INFORMATION FORMATS AND DECISION PERFORMANCE: AN EXPERIMENTAL INVESTIGATION

By

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A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1977

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ACKNOWLEDGEMENTS

I wish to express my gratitude to the University of Puerto Rico for financing my graduate program; to my dissertation adviser, Dr. Richard A. Elnicki, for his recurrent insistance and corrections throughout the course of this work; to my co-adviser, Dr. Jack M. Feldman, for his invaluable comments and stimulus; to the rest of my committee, Dr. Christopher B. Barry, Dr. Thom J. Hodgson, and Dr. Richard R. Jesse, for their help and suggestions at the various stages of the research; and to my colleague and friend, Jose F. Colon, for his enlightening suggestions during the early part of the project.

I also want to express special appreciation to my "parents" in Gainesville, Mr. and Mrs. Bruce Ruiz, for their long, long hours of companionship and friendship during my stay at the University of Florida.

Most important, I thank my wife, Magui, for pushing me through while taking the worst part; my sons, for the time they would have rather spent with me; and my parents, for their ever present support and counsel.

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for the Degree of Doctor of Philosophy

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June 1977

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Major Department: Management

This study examines some implications of the relationship between information format and decision performance. A real-life information-decision problem was abstracted to create a simulated decision environment in which alternative forms of presenting information relevant to the problem were manipulated and administered to 160 experimental subjects.

Multivariate and univariate analyses of the experimental data indicated significant differences due to the experimental treatments. Presentation style (tabular versus graphical) and information layout (I.D. ordering versus due-date ordering) were found to have separate and joint effects on decision performance. The style of presentation had a strong influence on subject choice behavior. The level of probabilistic information provided (point estimates versus interval estimates) and the style of presentation had a joint effect on

decision time. Subjects with few decision entities on their reports felt indifferent toward format, while subjects with many decision entities indicated clear format preferences.

The implications of the findings for the Management Information Systems researcher and practitioner are discussed. Suggestions are given for further research.

CHAPTER 1

RESEARCH BACKGROUND

1.1 Introduction

The last decade has seen a significant increase in the use of computer-based data systems to support decision making in organizations. This marriage of computers and organizations has developed into the rapidly growing field of Management Information Systems (MIS). In general, MIS refers to the use of computer-based data systems for the primary purpose of supporting management decisions. Since MIS exist to support decision making, researchers in the area have suggested that their effectiveness should be measured in terms of the effectiveness of the decisions they support. In turn, it has been argued that the effectiveness of decisions based on information will depend, among other things, on the accuracy, relevancy, and timeliness of the information.

More recently, it has also been proposed that even when information is adequate, its effective use can be influenced by the manner in which the information is presented, in particular, by its format of presentation, level of detail, and medium of transmission. This line of thought has led researchers in the area to investigate how the physical form of presenting the information can influence aspects of decision performance. That

relationship, in essence, is the object of this study. In the present research, the influence of information format on decision performance will be investigated in the context of a specific information-decision problem.

1.2 Literature Review

The increase in popularity of Management Information Systems during the last decade has been accompanied by an awareness of the need for improving the efficiency of the systems designed. The consensus of the researchers in the area has been that there is a need for a theory of MIS. Zannetos [31] states that a theory is needed to develop objective criteria for determining the effectiveness of MIS efforts. In response to the call for a theory, several research frameworks have been proposed [10, 16, 21, 22].[1]

1.2.1 The Minnesota Experiments

The research framework proposed by Chervany et al. [10] has guided the "Minnesota Experiments," a series of empirical studies that have been conducted at the Management Information Systems Research Center, University of Minnesota. The general purpose of these studies has been to manipulate various MIS variables to investigate their impact on decision performance. The Chervany et al. framework states that three categories of variables affect decision performance, P, given a particular information system. These are the decision environment, DE, the

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[1] These frameworks have not constituted theories, in the formal sense, but rather pre-theoretical lists of variables.

decision maker, DM, and the characteristics of the information system, CIS. In functional form,

$$P = f(DE,DM,CIS) \qquad (1.1)$$

A number of experiments have been conducted under this framework. They all appear to have followed Van Horn's [28] suggestion that laboratory studies provide an effective means for MIS research. In particular, the experimenters have drawn upon the technique of "experimental gaming" to create artificial decision-making evironments within which they have manipulated various aspects of the information system. In support of this technique, Barret et al. conclude:

> We have been unable, to date, to generate evidence which implies that the interpretation of decision performance results in terms of a treatment variable is likely to be confounded by the effects of the simulator and/or other aspects of the management game context [4, p. 11].

Dickson et al. say of experimental gaming:

> ...we are of the opinion that experimental gaming, despite its high cost, is an effective way of investigating this area. The major problems really are associated with the measurement of the variables included in the experiments. Somewhat surprisingly, problems of subject motivation and experimental control have been minor [12, p. 20].

Table 1.1 on pages 4 - 6 is a summary of some of the most referenced studies that have been conducted under the Chervany et al. framework. The variables that were experimentally controlled are shown in each case before the "given" bar (|) in the functional models along with a brief description of the measure used for each variable. Other

TABLE 1.1

SOME STUDIES CONDUCTED UNDER THE CHERVANY ET AL. FRAMEWORK

Experimenter [Reference]	Decision Environment/ Experimental Subjects	Basic Model	Experimental Variables	Measure	Results
Chervany and Dickson [9]	Production-Inventory/ Graduate Business students	P=f(CIS|DE,DM)	P	Cost, time confidence in the decisions	Subjects receiving the summary data treatments performed better cost-wise but took longer to make decisions. Subjects receiving the raw data treatments had more confidence in their decisions.
			CIS	Summary vs. raw data reports	
Schroeder and Benbasat [25]	Production-Inventory/ Undergraduate Business students	P=f(DE,CIS|DM)	P	System utilization, decision confidence	The frequency of information use was not affected by environmental variability. The low variability groups preferred less detailed reports. No decision confidence effects were established.
			DE	Variability in the decision environment at 3 levels: low, medium, high	
			CIS	Summary vs. detail reports	

TABLE 1.1 (continued)

Experimenter [Reference]	Decision Environment/ Experimental Subjects	Basic Model	Experimental Variables	Measure	Results
Senn and Dickson [26]	Purchasing Decisions/ Purchasing Managers	P=f(DM,CIS|DE)	P DM CIS	Cost, time, confidence, number of reports requested Decision makers from large and small organizations Paper reports vs. CRT, summary vs. detail reports	No significant relation was observed between organization size and the performance measures. The display media had a significant effect on the number of reports requested. The subjects receiving hard copy reports requested more information than those using the CRT medium. There was no significant difference in cost performance between users of summary and detail information.
Kozar [18]	Production-Inventory/ Graduate Business students	P=f(CIS|DE,DM)	P CIS	Cost, time, confidence, in the decisions CRT vs. hard copy reports	CRT users took significantly longer time to make decisions. They felt the device was useful as a filing organizer but were unhappy with the lack of hard copy. Subjects receiving the hard copy reports had lower costs. There was no difference in decision confidence between the two groups.

TABLE 1.1 (continued)

Experimental [Reference]	Decision Environment/ Experimental Subjects	Basic Model	Experimental Variables	Measure	Results
Benbasat and Schroeder [5]	Production-Inventory/ Students enrolled in an operations management course	P=f(DM,CIS|DE)	P	Cost, time, number of reports requested	Subjects using graphs had lower costs than subjects using tabular information. Subjects with graphical reports requested less reports than those with tabular reports. Low analytic subjects who neither had graphical reports nor decision aids had the largest costs. Low analytic subjects who had a low functional knowledge of the area requested the largest number of reports. There were no significant differences in time performance between the users of the graphical and tabular reports.
			DM	Decision-making style: low or high analytic; knowledge of functional area: low or high	
			CIS	Graphs vs. tabular information; decision aids: provided or not; number of reports available; necessary vs. overload groups	

items in the table are the nature of the simulated decision environment, the experimental stubjects, and a summary of the results.

It is interesting to note that while the form of presenting the information has been extensively considered in one form or another, the "layout" or physical arrangement of the information reported has not been manipulated as an experimental variable in any of the studies reviewed. Figure 1.2, part A (p. 8) is an example of the type of "form of presentation" treatment that has been manipulated in the reviewed literature. Figure 1.2, part B is an example of what is meant here by information layout. The influence of this variable on decision performance will play an important role in this study.

1.2.2 The Lucas Model

The model proposed by Lucas [21] includes essentially the same variables as the Chervany et al. framework, but it also takes into account the interface between use of the information system and performance. His descriptive model states that performance (P) is a function of situational, personal, and decision style variables (the DM group in the Chervany et al. model), the quality of the information system (the CIS group in the Chervany et al. model) and the analysis and actions taken by the users (similar to the DE group in the Chervany et al. model). In addition, his model also states that the performance of the information system is independently affected by the use of the system, U. In functional form,

$$P = f(DE,DM,CIS,U) \qquad (1.2)$$

Raw Data Treatment

FINISHED GOODS INVENTORY HISTORY

	WEEK 1 OF MONTH 3			WEEK 2 OF MONTH 3		
INVENTORY LEVELS						
	Resinoid	R-Forced	Vitrifid	Resinoid	R-Forced	Vitrifid
MONDAY	0	371	0	0	120	481
TUESDAY	39	102	82	0	153	191
WEDNESDAY	0	0	198	0	202	0
THURSDAY	34	36	299	38	267	0
FRIDAY	71	84	393	79	188	38
STOCKOUTS						
	Resinoid	R-Forced	Vitrifid	Resinoid	R-Forced	Vitrifid
MONDAY	235	0	58	354	0	0
TUESDAY	0	0	0	423	0	0
WEDNESDAY	379	321	0	144	0	201
THURSDAY	0	0	0	0	0	121
FRIDAY	0	0	0	0	0	0

Statistically Summarized Treatment

FINISHED GOODS INVENTORY HISTORY
SUMMARY STATISTICS CALCULATED
FROM OPERATIONS FOR PERIOD
WEEK 1 OF MONTH 3 THROUGH WEEK 4 OF MONTH 3

	Daily Inventory Levels (End of Day)				Stockouts		
	Resinoid	R-Forced	Vitrifid		Resinoid	R-Forced	Vitrifid
Mean	23.25	140.80	92.85	Mean	171.30	38.20	123.70
Coef Var	6.26	4.18	7.97	Coef Var	5.63	14.77	7.09
Maximum	79.00	371.00	481.00	Maximum	427.00	392.00	484.00
Range	79.00	371.00	481.00	Range	427.00	392.00	484.00

A. Abreviated samples of two "form of presentation" treatments used by Chervany and Dickson [9, p. 1338].

FINISHED GOODS INVENTORY HISTORY
SUMMARY STATISTICS CALCULATED
FROM OPERATIONS FOR PERIOD
WEEK 1 OF MONTH 3 THROUGH WEEK 4 OF MONTH 3

	Mean	Coef Var	Maximum	Range
Daily Inventory Levels (End of Day)				
Resinoid	23.25	6.26	79.00	79.00
R-Forced	140.80	4.18	371.00	371.00
Vitrifid	92.85	7.97	481.00	481.00
Stockouts				
Resinoid	171.30	5.63	427.00	427.00
R-Forced	38.20	14.77	392.00	392.00
Vitrifid	123.70	7.09	484.00	484.00

B. A different "layout" for the information in the second report above.

Figure 1.2 Different formats of presentation

In a field study [20] with an actual information system and data from salesmen's performances, Lucas observed relationships among DE, DM, CIS, and P that are congruent with those observed in the "Minnesota Experiments." In addition he also noted the following relationship between performance and information system use:

$\frac{\Delta P}{\Delta U} > 0$ when relevant information is provided and used,

$\frac{\Delta P}{\Delta U} < 0$ when the information provided is irrelevant to the decisions that must be made.

What he in effect noted is that only those information system designs that promote effective use of the information will have a positive effect on performance. One of the indications of his results was that information structure elements such as the format of presentation, F, and the level of detail, L, can be determinants of effective use, EU, given other system characteristics, CIS', and a given set of DM and DE variables. Although not explicitly stated in his paper, the results of his study suggest that

$$EU = f(F,L|DE,DM,CIS') \tag{1.3}$$

and that

$$P = F(EU|DE,DM,CIS') \tag{1.4}$$

with $\frac{\Delta P}{\Delta EU} > 0.$

These relationships are inferred from the discussion part of his paper:

> One of the most important implications of the model and results is that different personal, situational and decision style variables appear to affect the use of systems. These findings argue for more

> flexible systems to support different users' needs. For example, the present sales information system could be modified to provide different output formats and levels of summarization [20, p. 918].

Equations 1.3 and 1.4 are combined in the next chapter to produce a model that will serve as a guide for evaluating a set of propositions relating information format to decision performance.

1.2.3 Other Related Literature

In addition to the literature referenced above, other related literature has influenced the formulation of the hypotheses evaluated in the present study. Two textbooks on MIS, in particular, contain some interesting but undocumented ideas which have shared in the latter. Murdick and Ross [23] make such general statements as, "In general, the format should be established to save the manager's time" [p. 326] and, "Managers prefer graphic displays, which reduce large amounts of information into easily understood pictorial form" [p. 263].

The second MIS text which makes similar suggestions is Voich et al. [29]. They propose:

> Format is important because it affects the ease with which the report can be read and assimilated. As the complexity of a report increases, its likelihood of extent of use falls [29, p. 229].

This writer feels that the authors are saying that more attention should be given to the format of the report as the number of "entities" in the report on which decisions are required increases.

Finally, a recent paper by Conrath [8] suggests:

> In all the literature on decision making, and in particular that on statistical de-

> cision theory, little if anything has been said about the form in which the data should be presented to the decision maker. Perhaps this is because most theoreticians assume that as long as the data unambiguously define the distributions, the format of presentation should make no difference. This brings up the question of whether data can ever be unambiguously presented, and perhaps more importantly, in whose eyes? The only answer to the second question is the user, but he has seldom been asked [8, p. 878].

Conrath goes on to propose that the format in which probabilistic data is presented as a basis for choice can influence choice.

The present study centers around the questions raised above as they relate to a pragmatic "how-do-we-present-the-information?" problem.

1.3 Organization of the Dissertation

In Chapter 2, a "real-life" information-decision problem is presented to provide a setting for the questions investigated in this study. The nature of the problem is explained in Section 2.1. In Section 2.2, the information needs of the manager in the problem are considered, and it is assumed that these needs are relatively well defined and structured. A number of questions related to the form in which information should be presented to the manager are raised in Section 2.3. The results of previous studies are revisited in an effort to provide orientation to the present information format/decision performance questions. The criteria used to measure decision performance are defined in Section 2.5, and a set of research hypotheses relating these criteria to the experimental format variables is presented in Section 2.6. In Section 2.7, a general model is presented to serve as the guide for the experiment.

The nature and details of the experiment are the subject of Chapter 3. The methodology is discussed in Section 3.1 and a full description of the experimental task is given in Section 3.2. Section 3.3 discusses the experimental results that should be observed for the research hypotheses to be supported, and a table is presented that shows how each of the hypotheses is to be evaluated from the experimental data.

The statistical results of the experiment are presented in Chapter 4. These are discussed in Chapter 5 from the point of view of their implications for both the MIS researcher and practitioner. In Chapter 6, suggestions are given for new lines of research.

CHAPTER 2

THE PROBLEM

2.1 An Information-Decision Problem

The information-decision problem that provided the setting for the current study is presented in this chapter. The situation studied presents several advantages from the point of view of empirical MIS research. First, the situation is relatively simple, easy to characterize and to model. Second, the problem points to clearly definable questions of information structure, an area that has received increased attention in the recent MIS literature [5, 9, 12, 18, 25, 26]. Finally, the situation may represent a new area for the application of MIS technology.

2.1.1 The Real-Life Problem

The particular decision situation to be outlined comes from the field of agriculture and concerns the detection of estrus (heat) in artificially inseminated dairy herds. The problem is that failure to detect heat can result in lost breeding opportunities, lower milk production, and subsequent capital losses. The following excerpts from the dairy industry literature illustrate the problem:

> Accurate estrus detection is a key to efficient reproduction and high milk production. . . .Proper detection of estrus is essential in any planned breeding program using hand mating, especially to capitalize on superior sires available through artificial insemination [14, p. 248].

> ...delayed conception means a cow must stand dry and nonproductive when her lactation ceases at a maintenance cost of about $20 per month [19, p. 580].
>
> Approximately 53% of heats are being missed. . . .Dairymen appear to be losing twice as many days due to missed heat periods as due to failure to conceive [2, p. 247].

The literature includes much advice about methods for heat detection, most of it having to do with heat recognition in the field. Even then, it has been suggested that close to 50% of all heats are not detected [2, 3].

Dairymen using artificial insemination and keeping the appropriate records have information that can help them in detecting heat [7]. The information consists of the date of the last service (insemination) of each cow and data on the average number of days between successive services. It has been suggested [27] that a chart with "heat expectancy dates" could be valuable for detecting heat, as it would enable the dairyman to concentrate his observations on those cows expected to come in heat.

The design of such a report motivated initial work on the problem. A preliminary survey[1] using an experimental report in an actual dairy operation revealed that rather general agreement existed among the prospective users as to the desired content of the report and how often

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[1] Unpublished; conducted at the dairy farm of Mr. Herman Hernandez, Isabela, Puerto Rico during January-May, 1976.

it should be produced. One issue that remained questionable was the manner in which the information should be presented in the report. There were several formats that appeared useful but each seemed to have its own pros and cons from the point of view of ease of use. The problem appeared to be sufficiently interesting and important to merit an experimental evaluation of the various information format alternatives.

The problem discussed in the next section is the abstraction or prototype designed to investigate this information structure problem within a controlled laboratory setting.[1] The questions of interest were widened to include a set of propositions related to a more general MIS framework and theory. In the problem to be outlined below, the term "heat" is replaced with more general terminology.

2.1.2 The Abstracted Problem

Consider an organization that needs to keep records on a number of random events that occur relatively infrequently but are important to management. These events represents opportunities for management: if one occurs and is not detected the organization suffers opportunity costs.

Management knows that these events occur independently approximately once every 20 days, and that when they occur they are "detectable" during a short period of time (approximately 24 hours).

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[1] The reasons for taking the research to the laboratory were two-fold. First, resources were not available for conducting a reasonably controlled field experiment. Second, the research interests of the author were shifted from the operational considerations of the problem to a more general set of research questions more amenable for resolution in a laboratory setting.

It is assumed that each check made on an event to see whether it is occurring has a fixed unit cost associated with it, independent of the number of checks made on the same day. It can, therefore, be uneconomical for management to check on these events too often. Management is assumed to maintain a computer-based data bank with the following data on the process:

(1) a three-digit identification (I.D.) number for each event that is expected to occur during the next twenty days,

(2) the date of the last observed occurrence of each event, and

(3) data on past time intervals between successive occurrences of each event.

It is further assumed that management will use this data to produce a periodic report to aid them in deciding which events to check at the beginning of each day.[1] Their decision problem is relatively well structured and straight-forward: they would like to detect as many of these events as possible but face a trade-off between the costs of "checking" and "missing" the events.

2.2 Information Content

Based on past experience, the managers in charge of checking the events know that it is not cost-effective to check an event except on those days when the event is more likely to occur, i.e., the days around the date figured by adding 20 days to the last observed occurrence. They have suggested that a periodic chart with "event

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[1] They will produce the report; they will rather have the data reported in its worst possible form than no report at all.

expectancy dates" would be useful as it would permit management to concentrate their checks on those days when each event is expected to occur.

A dichotomy from economic models will help to clarify the type of report that managers consider appropriate in the problem modeled. Managerial reports can be descriptive or normative in nature. Purely descriptive reports, as used here, are those limited to the presentation of factual information (e.g.: production history reports, financial reports). Purely normative reports, as used here, explicitly indicate courses of action to be followed by the user (e.g.: production schedules). All managerial reports can be placed on this descriptive-normative scale. A report providing demand forecasts and safety stock sizes [11] is, for example, more normative than one providing a detailed sales history but no forecasts. In this study, it is assumed that managers want more than a descriptive report (for example, one showing only the dates of the last observed occurrence of each event). They want a report providing forecasts for the event occurrence dates. They consider twenty days a reasonable time horizon for the report. It is assumed that shorter horizons would make the report too costly to produce and longer horizons would make the forecast data basis too dated. In conclusion, the report that is assumed to be appropriate for the problem modeled is a periodic chart containing event I.D. numbers and "expected due-dates" for those events expected to occur within the next twenty days.

2.3 The "How-Do-We-Present-the-Information?" Problem

The information content needs of management in the problem characterized above are assumed to be relatively well structured and defined. The issue that constitutes the main focus of this research

is the question of information structure, i.e., the physical manner in which the information is presented to the user. Dickson et al. have suggested three categories of information structure (enumerations added by the author):

> It is naive to assume that information system requirements do not vary with the type of decision being formulated. And, it is sub-optimal to continue developing information support systems without serious consideration of (1) the form in which information is provided, (2) the level of detail incorporated into ensuing reports, and (3) the media by which the information in transmitted [12, p. 3].

The medium of transmission, the format of presentation, and the level of detail are discussed below in terms of their importance in the defined decision problem. In each case, arguments are presented to show why each category was included or excluded as an experimental variable in the study. The dependent variables measuring decision performance are then presented, and the questions raised about the effects of the experimental treatments on performance are presented as a set of testable hypotheses. In the final section, a functional model is presented to serve as framework for testing the hypotheses.

2.3.1 Medium of Transmission

Two media are commonly used for reports generated from a computer-based data bank: paper printout and cathode ray tube (CRT) display.[1] In the case of a report that is to be produced and released

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[1] When reports are generated by a computer, the choice of transmission medium is usually confined to these two media. Otherwise, the writer is aware that other more "personalistic" modes of communication are also available for displaying the information to the user [22]. Only computer

every twenty days, paper would appear to be the more appropriate medium. A CRT could be a reasonable medium if the time interval between reports was shorter and if there was a need to reduce paper clutter. Kozar [18] found that users of CRT's tend to to be unhappy with the lack of hard copy and that they take significantly more time to arrive at decisions than hard copy users. The medium of transmission was not considered a relevant design variable in the present study. Conventional paper printout was used as the constant medium throughout the experiment.

2.3.2 Format of Presentation

The format variable has been discussed more extensively in the MIS literature than the medium variable [5,9,25,26]. The most common format treatment has been summary versus raw data [9, 25,26]. This treatment, however, has manipulated the data content more than its format. Only one study has been concerned with format, if format is considered to be related to the "style" of presentation.

Style of presentation. Benbasat and Schroeder [5] presented daily production figures to experimental subjects in one of two styles: tabular and graphical. The tabular style listed daily production figures while the graphical style plotted the same daily figures versus time. Their results indicated that subjects using the graphical reports had lower costs, with no significant differences in decision time between the two groups.[1] These results suggest that the graphical format might

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generated reports are considered here, however, mainly because of the lack of resources for experimenting with other media.

[1] Murdick and Ross [23, p. 263] state that managers prefer graphical displays, although they do not support their contention.

be a more appropriate style of presentation for the time-staged information in our problem. Specifically, if the reports are to consist only of event I.D. numbers and expected due-dates, the question of interest is whether the formats shown in Figure 2.1 (p. 21) can influence aspects of decision performance. As discussed in section 2.5, decision performance will be measured in this study in terms of time performance (the time devoted to making the "check" decisions) and cost performance (the total cost of checking and missing the events).

A priori, it would seem logical to expect the formats in Figure 2.1 to influence, if anything, time performance. The dates reported are future dates and the information is going to be used chronologically. Consequently, the time dimension added by the graphical style should be helpful in that it orders the events chronologically from left to right on the x-axis[1]. In part C of Figure 2.1, for example, it is seen that event "032" is expected to occur first (May 26), then event "146" (May 28), and so on.

Information layout. A chronological ordering of the events can also be achieved with the tabular style by arranging the events in order of expected due-dates, as in part B of Figure 2.1. It is assumed, however, that the ordering of events by ascending I.D. numbers is a desirable condition in these reports because management frequently needs to make quick reference to the due-dates of particular events. The quickest way to make these references is when the events are arranged

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[1] If these reports were intended for chinese managers, an attempt would be made to present the information from right to left.

A. Tabular style with I.D. layout

EVENT IDENT.	EXPECTED DUE-DATE (MONTH-DAY)
004	6-07
009	5-29
017	6-11
024	6-04
032	5-26
038	6-04
051	5-31
070	6-01
076	6-10
078	5-30
082	6-03
085	6-10
097	6-05
110	6-11
121	6-05
128	6-01
142	6-09
146	5-28
155	6-12
163	6-09
168	6-07
171	5-31
173	6-06
177	6-06
186	5-31

B. Tabular style with due-date layout

EVENT IDENT.	EXPECTED DUE-DATE (MONTH-DAY)
032	5-26
146	5-28
009	5-29
078	5-30
171	5-31
051	5-31
186	5-31
070	6-01
128	6-01
082	6-03
024	6-04
038	6-04
121	6-05
097	6-05
173	6-06
177	6-06
168	6-07
004	6-07
163	6-09
142	6-09
085	6-10
076	6-10
110	6-11
017	6-11
155	6-12

C. Graphical style with I.D. layout

EXPECTED DUE-DATES

EVENT IDENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IDENT.
004														H							004
009					H																009
017																		H			017
024											H										024
032		H																			032
038											H										038
051							H														051
070								H													070
076																	H				076
078						H															078
082										H											082
085																	H				085
097												H									097
110																		H			110
121												H									121
128								H													128
142																H					142
146				H																	146
155																			H		155
163																H					163
168														H							168
171							H														171
173													H								173
177													H								177
186							H														186
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Figure 2.1 Three forms of presenting the expected due-dates information

in ascending I.D. number order, especially when there are a large number of events to be referenced. One solution to this dual need is to produce two reports: one in order of expected due-dates to support the daily checking of decisions, and another in ascending I.D. order for quick references. But, if an experiment revealed no significant difference in performance between the users of the graphical I.D. ordered reports and the users of the due-date ordered reports, the implication would be that there is no need for both reports. The graphical report would provide the two desired features. Another explanation for that result could be that the graphical style in this case has a "calendar" resemblance and therefore presents a more familiar picture to the user than a listing of numbers. If this were the case, a graphical report that presented the events in due-date order might also influence performance. Figure 2.2 below shows such a report.

EXPECTED DUE-DATES

EVENT IDENT.	MAY 25	26	27	28	29	30	JUNE 31	01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IDENT.
032	H																				032
146				H																	146
009					H																009
078						H															078
171							H														171
051							H														051
186							H														186
070								H													070
128								H													128
082										H											082
024											H										024
038											H										038
121												H									121
097												H									097
173													H								173
177													H								177
168														H							168
004														H							004
163																H					163
142																H					142
085																	H				085
076																	H				076
110																		H			110
017																		H			017
155																			H		155
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Figure 2.2 Graphical style with events in due-date order

The only difference between the arrangement above and that in part C of Figure 2.1 is the "layout" of the information in the report. The term "layout" will be used here to refer strictly to the order in which the information is arranged in the report. Two layout schemes are considered: I.D. number ordering and expected due-date ordering.

Questions of interest. The format alternatives considered above appear to have pros and cons from the point of view of the ease with which the report can be used. The format variables layout and style will be experimentally manipulated in an attempt to address the following questions:

(1) Can information layout by itself affect decision performance?

(2) Can information layout interact with presentation style to enhance or reduce separate performance effects of either layout or style?

2.3.3 Level of Detail

Given the probabilistic nature of our data, a wide range of levels of detail can be provided in the "expected due-dates" reports. These could range from point estimates to complete probability distributions of the event occurrence times. On this subject, Conrath [8] proposes that decision makers are not likely to think in terms of probability distributions, and that they prefer to think in terms of, and use, point estimates. His argument would suggest the use of point estimate forecasts as one level of detail in this study. The question would remain, however, whether the users in this decision context could benefit from additional information about the

probability distributions from which these estimates are drawn. This additional information could be presented, for instance, in the form of percentiles of the distribution (e.g.: the days lying above the fifth percentile and below the ninety-fifth percentile of the distribution). The latter would have the advantage of incorporating information about the variability of the event occurrence times and, therefore, the risk involved in making the check decisions.

In the problem modeled, it is assumed that there is enough data available on past intervals between events to permit estimates of the mean, $\bar{x}_i$, and standard deviation, s_i, for each event i. Using this data, and assuming normal and stable distributions, the intervals $\bar{x}_i \pm 2s_i$ were used as interval estimates for the days during which each event i is more likely to occur. In the case of the tabular style, the reports with such "95% confidence intervals" could appear as in parts A and B of Figure 2.3 (p.25). The issue of format takes new importance now since it is possible that the graphical style (part C of Figure 2.3) may have properties that make the checking choices easier for the user. Specifically, the level of probabilistic detail (point estimates or interval estimates) may interact with the style of presentation (tabular or graphical) to affect the ability of the user to process and effectively use the information.

Questions of interest. The two levels of probabilistic information described above, point estimates and interval estimates, will be experimentally manipulated in connection with the format variables to address the following questions:

A. Tabular style with I.D. layout

EVENT IDENT.	95% CONFIDENCE INTERVAL (FIRST DAY, LAST DAY)
004	6-06 , 6-09
009	5-27 , 5-31
017	6-10 , 6-12
024	6-01 , 6-07
032	5-25 , 5-28
038	6-02 , 6-05
051	5-29 , 6-03
070	5-31 , 6-02
076	6-09 , 6-12
078	5-27 , 6-02
082	6-01 , 6-05
085	6-09 , 6-14
097	6-04 , 6-07
110	6-10 , 6-12
121	6-03 , 6-07
128	5-30 , 6-04
142	6-06 , 6-12
146	5-26 , 5-30
155	6-11 , 6-13
163	6-07 , 6-12
168	6-04 , 6-10
171	5-28 , 6-03
173	6-05 , 6-07
177	6-05 , 6-08
186	5-29 , 6-03

B. Tabular style with due-date layout

EVENT IDENT.	95% CONFIDENCE INTERVAL (FIRST DAY, LAST DAY)
032	5-25 , 5-28
146	5-26 , 5-30
009	5-27 , 5-31
078	5-27 , 6-02
171	5-28 , 6-03
051	5-29 , 6-03
186	5-29 , 6-03
128	5-30 , 6-04
070	5-31 , 6-02
082	6-01 , 6-05
024	6-01 , 6-07
038	6-02 , 6-06
121	6-03 , 6-07
168	6-04 , 6-10
097	6-04 , 6-07
173	6-05 , 6-07
177	6-05 , 6-08
004	6-06 , 6-09
142	6-06 , 6-12
163	6-07 , 6-12
085	6-09 , 6-14
076	6-09 , 6-12
110	6-10 , 6-12
017	6-10 , 6-12
155	6-11 , 6-13

C. Graphical style with I.D. layout

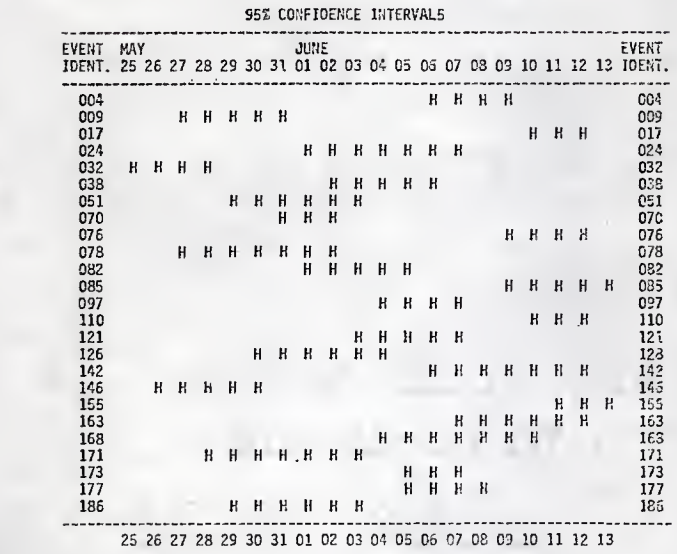

Figure 2.3 Three forms of presenting the interval estimates information

(1) Can users of probabilistic data make effective use of information beyond point estimates?

(2) Can the format in which probabilistic data is presented affect choice behavior?

(3) Can the level of probabilistic information interact with format to affect user performance?

2.4 Number of Decision Entities

An important consideration is now introduced: the influence that any report format will have is very likely to be related to what is called here the "number of decision entities" on the report. The term "decision entities" will be used to refer to the separate pieces of information present on a report and on which decisions are required. In the real problem this study is based on, there is little doubt that the report users would be indifferent about format if their reports contained information on only two or three events. This is not expected to be the case, however, if the reports contain information on 200 events.[1] The "number of of decision entities" was included as an experimental variable to empirically test the assertion that while report users may feel indifferent about format when small amounts of information must be processed, they will move toward preferred formats, and their performance will be more sensitive to format as the amount of information they must process increases.[2]

---

[1] A manager dealing with more than 200 decision events told the writer he "could care less" about format if he did not have so many events to look after.

[2] "Amount of information," as used here, must not be confused with "information overload," a condition where the decision maker is given too much, unnecessary information [1, 9, 15].

2.5 Dependent Variables

Time performance. Since time is a valuable managerial commodity, decision time is commonly used as a decision performance criterion [5,9,18,26]. Although not supported by any studies, Murdick and Ross contend that "... format should be established to save the manager's time" [23, p. 326]. Decision time will be used here as a proxy for the value of managerial time to the organization. It will be measured by the total time that the decision maker devotes to making the checking decisions. It is expected that this measure will be correlated with the cost measure, although the cost measure will not include the cost of managerial time to avoid double counting. Chervany and Dickson [9] found that some decision makers will take longer to arrive at their decisions but will make lower cost decisions. The possible correlation between the time and cost measures will be taken into account through the use of multivariate statistical procedures (viz., MANOVA).

Cost performance. Cost is also commonly used as a performance criteria when decision effectiveness is discussed [5,9,18,26]. Cost performance will be measured here by the total of the "checking" and "missing" costs. For each check made, the decision maker will incur a fixed dollar cost. The checking cost, then, will be given by the product of the total number of checks made times the fixed cost per check. For each event that is not detected, the decision maker will incur a fixed opportunity cost. The cost of missing is then calculated as the product of the total number of misses times the fixed cost per miss.

Choice behavior. Choice behavior was also included as a criterion variable to test Conrath's [8] contention that the format in which

probabilistic data is presented influences the choice behavior of the user. It was assumed this could be the case with the tabular versus graphical formats in the current study. The graphical format appears to "bring out" more vividly the information, especially in the case of the interval estimates (see Figure 2.3, p. 25). The measure used for choice behavior was the number of checks performed by the decision maker, disregarding which were successful and which were not.

2.6 Research Hypotheses

The questions raised above are now presented as six testable hypotheses. Three of the hypotheses relate to format, two to the level of detail, and one to the number of decision entities in the report. The hypotheses relating to format are presented first.

1. The layout or physical order of the information in a report can reduce decision time. In this case, it is expected that the users of the due-date ordered reports will have shorter decision times than the users of the I.D. ordered reports. (H1)

This hypothesis was not found to have been considered in the MIS literature, either in field or laboratory work. There are many ways in which the same information can be arranged in a report. Even though the "best" way may usually be considered "apparent" or the issue simply "unimportant," this may not always be the case.

2. The format in which probabilistic data is presented as a basis for choice can influence choice. In this case, it is expected that the graphical report users will choose to make more checks than the users of the tabular reports. (H2)

This hypothesis was suggested by Conrath [8] but not statistically demonstrated in his paper. He states:

> Apparently format has the characteristic that it can focus one's attention on one

> dimension of the choice space, and that dimension becomes paramount in the decision process. ...Whether the attention focusing attributes of data format are the keys to the influence that format has on choice is a question not yet resolved. But the question would appear to be sufficiently important that it should no longer be ignored [8, p. 880].

The format variable that is expected to have "attention focusing attributes" in this case is the style variable (graphical versus tabular). As such, the style factor will be the one analyzed in the evaluation of this hypothesis.

3. Report layout and style can interact to enhance or reduce the decision time effects of a particular layout or style. In this case, it is expected that the users of the I.D. ordered reports in graphical style will have shorter decision times than the users of the same layout in tabular style. (H3)

The objective in testing this proposition is to demonstrate the existence of information format characteristics that may have joint effects on decision performance. Here, the combination of the I.D. ordering layout with the graphical style is expected to reduce the long decision times associated with the absence of the convenient due-date ordering.

The next two hypotheses relate to the level of detail of the probabilistic information provided.

4. Users of probabilistic data can make effective use of information beyond point estimates. In this case, it is expected that the interval estimates users will make more cost-effective decisions than the point estimates users. (H4)

The interest in this hypothesis is twofold. First, its evaluation should give an indication as to whether the users of this type of

report can make effective use of interval estimates. In the real problem this study is based on, it is expected that interval estimates can be useful. Second, this proposition provides a setting for testing Conrath's [8] contention that decision makers are not likely to think in terms of probability measures other than point estimates.

5. The time to process and effectively use probabilistic information is related to the format in which the information is presented. In this case, it is expected that the users receiving the interval estimates in the graphical style will have shorter decision times than those receiving the interval estimates in the tabular style. (H5)

The difference between H1 and H5 is that H1 refers to the direct (main effect) influence of layout on performance while H5 refers to the interaction between a format variable (style) and the level of probabilistic information provided (point estimates or interval estimates). The purpose in testing this hypothesis is to show that different levels of probabilistic information will be more easily processed and used with different formats of presentation.

The hypothesis relating the number of decision entities to format preference is:

6. Report users will move from format indifference to format preference and their performance will be more sensitive to format as the number of decision entities on their report increases. In this case, no significant format opinion differences are expected among users of reports with few decision entities in them, with the opposite expected among users of reports containing many decision entities. Differences in performance are also expected to be larger among the users of the reports with many decision entities. (H6)

The objective in testing this proposition is to demonstrate the existence of a "number of decision entities" variable that should be

considered in MIS design. This variable will occur in most situations where the number of physical phenomena on which decisions are required is variable. A procurement manager, for instance, may be indifferent about the format of his inventory status reports if he must place orders for only five items. He would probably be concerned about format (and his performance would be more influenced by format) if he has 250 items on which to place orders.

2.7 Basic Functional Model

The following model presents, in equation form, the relationships to be analyzed.

Given equations 1.3 and 1.4,

$$EU = f(F,L|DE,DM,CIS') \tag{1.3}$$

$$P = f(EU|DE,DM,CIS') \tag{1.4}$$

it follows that

$$P = f(F,L|DE,DM,CIS') \tag{2.1}$$

where, P = decision performance

F = format of presentation

L = level of detail

DE = decision environment characteristics

DM = decision maker characteristics

CIS' = other characteristics of the information system.

In words, equation 2.1 states that the format of presentation and the level of detail are determinants of decision performance

given a particular decision environment, decision maker, and other characteristics of the information system. In the next chapter, a table is presented that shows each of the research hypotheses expressed as a variant of this basic model.

CHAPTER 3

THE EXPERIMENT

3.1 Method

This chapter presents the details of the experiment that was conducted to evaluate the decision performance effects of four factors: information layout, style of presentation, level of detail, and the number of decision entities on the report. The material has been arranged as follows. Section 3.1.1 discusses the nature of the experimental subjects. The methods used for collecting and analyzing the experimental data are presented in Section 3.1.2. A full description of the experimental task is given in Section 3.2. Finally, the experimental results that should be expected for the hypotheses to be backed up are discussed in Section 3.3.

3.1.1 Subjects

One-hundred sixty subjects participated in the experiment. The subjects were undergraduate students in Business Administration who had completed the first semester of introductory statistics at the University of Puerto Rico, Mayaguez Campus. They were invited to participate through announcements placed on bulletin boards and read in classrooms. No monetary incentives were offered but the rate of volunteering was high: an initial "sign-up" list yielded more than 200 subjects.

Ten subjects were randomly assigned to each of the sixteen (four factors each at two levels) experimental conditions. The assignments were made with a random number generator that uniformly distributed the numbers 1 through 160 among the sixteen conditions until a schedule was formed with ten numbers assigned to each condition. As subjects arrived to participate, their order of arrival was checked against the schedule to determine their condition assignment. It was felt that this assignment scheme avoided the problem of making individual subject "appointments" at the same time that it provided a means for stratifying the assignment of the experimental conditions through the three months it took to complete the study.

3.1.2 Design and Analysis

Table 3.1 (p. 35) is a summary of the 2^4 factorial experimental design. The two levels for the number-of-decision-entities variable were achieved by dividing the experimental subjects into two groups. One group was assigned to an experimental condition where only five events of interest had to be checked, referred to below as the "few decision entities" condition. The five events were selected to form a stratified representation of the twenty-five events that would take place in the "many decision entities" condition. User preference for particular formats was measured with a questionnaire administered to the subjects at the end of the simulation runs (see Appendix B, p. 78). In this study, no significant differences in format preference ratings are expected between the various format combinations among subjects assigned to the few-decision-entities group. Significant opinion differences, however, are expected among the ratings of the subjects

TABLE 3.1

FACTORIAL DISPLAY AND FACTOR LEVELS

A_1								A_2							
B_1				B_2				B_1				B_2			
C_1		C_2		C_1		C_2		C_1		C_2		C_1		C_2	
D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2	D_1	D_2
Condition 1	Condition 9	Condition 3	Condition 11	Condition 5	Condition 13	Condition 7	Condition 15	Condition 2	Condition 10	Condition 4	Condition 12	Condition 6	Condition 14	Condition 8	Condition 16

A. Factorial Display

Factor	Identification	Level 1	Level 2
A	Information Layout	Order by I.D.	Order by Due-date
B	Style of Presentation	Tabular Style	Graphical Style
C	Level of Detail	Point Estimates	Interval Estimates
D	Decision Entities	Twenty-five	Five

B. Factor Levels

assigned to the many-decision-entities group. Differences in decision performance are also expected to be larger for the many decision entities group.

Each of the sixteen resulting cells contained observations of 10 subjects' decision time, total checks made, total cost, and the five ratings to the format opinion questionnaire.[1] The data was analyzed using Multivariate Analysis of Variance (MANOVA).[2] MANOVA procedures have the advantage of considering correlation among the dependent variables [6]. Peter et al. [24], suggest that the technique should be used, as opposed to the univariate ANOVA, whenever there is reason to believe that multiple dependent varialbes might be correlated. Winer [30, p. 232] points out that by considering possibly correlated dependent variables in a series of independent univariate tests, one fails to obtain information about the total effect of the experimental treatments on all the criteria simultaneously. In the case of experimental MIS research, a close correlation has been suggested between time and cost, two of the criteria most frequently considered in the literature. In none of the reviewed literature, however, was MANOVA used.

In the current study, separate ANOVA's will be conducted on each of the dependent variables after overall significance is obtained

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[1] Decision time was rounded to the nearest minute and did not include the time devoted to the post-experimental questionnaire. The subjects were clocked as soon as their last "check" decision was made.

[2] BMD12V - Multivariate Analysis of Variance and Covariance, Health Sciences Computing Facility, Department of Biomathematics, School of Medicine, University of California, Los Angeles, 1976, p. 751.

by MANOVA. This procedure is necessary in order to evaluate directional hypotheses relating to specific dependent variables. Further investigation into the directions of obtained differences will be conducted using Scheffé's posthoc test for comparisons between means [17, pp. 483-486].

3.2 Experimental Task

The experimental subjects acted as the decision makers in the problem described in Chapter 2. A computer simulation of the decision environment was created which modelled the essential features[1] of the decision problem. Those features are:

1. The decision maker wants to detect a number of events that occur at random with normally distributed intervals between successive occurrences.
2. He has data on the random events and wants to use it to make cost-effective decisions on when to check each event.
3. He incurs a fixed opportunity cost for each event that occurs and goes undetected.
4. He incurs a fixed cost for each "check" that he makes on an event.
5. His objective is to minimize the total combined costs of "checking" and "missing" the events.

These features were incorporated into the simulation model as follows:

1. A hypothetical data set for the means, $\bar{x}_i$, and standard deviations, s_i, for the between occurrences interval of each event i was used to generate "actual" occurrence

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[1] Van Horn recommends that a good guide in developing an effective prototype is "to restrict the prototype content to the minimum set of features that are directly relevant to the problem modeled" [28, p. 179]. His advice was followed here.

dates for a number of hypothetical events.[1] Table 3.2 (p.39) shows that data in two parts: the data used for generating the 25 events in the "many decision entities" condition, and the data used for generating the 5 events in the "few decision entities" condition. The "generator" was validated to verify that the events were generated according to a normal distribution with the means and standard deviations indicated in Table 3.2.

2. Based on the data on Table 3.2, forecasts for the event occurrence dates were prepared and presented in report form. These were the experimental reports (conditions) administered to the subjects to help them in making their daily check decisions. Several of these reports have already have been shown in Chapter 2. The rest are shown in Appendix A, p. 69.

3. The subjects were told that undetected events at the end of the simulation would cost them $5 each.[2] These will be counted and multiplied by $5 to determine their total "missing" cost.

4. Subjects were also told that each and every check made during the run would be charged at $1 per check. These would be counted at the end of the run to determine their total "checking" cost.

5. Finally, subjects were instructed that their objective in the game was to minimize their total cost figured as the sum of their "checking" and "missing" cost. Subjects were told that their run time was also being measured, but were given no time limit or other time pressures.

Subjects interacted with the simulator through typewriter-type computer terminals in deciding which events to check for at each of twenty decision points (days). At each decision point, the subject chose the I.D. numbers of the events he wanted to check and entered them for processing by the simulator. The simulator reported whether or not the events checked occurred on that day, i.e., whether the checks were successful or not.

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[1] Another Van Horn guide followed here in developing the present prototype is "...to replace large actual data bases with small, carefully stratified representations." [28, p. 179].

[2] This and subsequent dollar figures were also simulated. No monetary incentive scheme was used to make subjects do "their best."

TABLE 3.2

DATA FOR THE EXPERIMENT

Event I.D.	Date of Last Occurrence	Number of Days between Occurrences	
		Mean ($\bar{x}_i$)	Standard Deviation (s_i)
004	5-18	20.5	1.00
009	5-9	20.0	1.25
017	5-22	20.0	0.75
024	5-15	20.0	1.75
032	5-6	20.5	1.00
038	5-15	20.0	1.25
051	5-11	20.5	1.50
070	5-12	20.0	0.75
076	5-21	20.5	1.00
078	5-10	20.0	1.75
082	5-14	20.0	1.25
085	5-21	20.5	1.50
097	5-16	20.5	1.00
110	5-22	20.0	0.75
121	5-16	20.0	1.25
128	5-12	20.5	1.50
142	5-20	20.0	1.75
146	5-8	20.0	1.25
155	5-23	20.0	0.75
163	5-20	20.5	1.50
168	5-18	20.0	1.75
171	5-11	20.0	1.75
173	5-17	20.0	0.75
177	5-17	20.5	1.00
186	5-11	20.5	1.50

A. Data for the many-decision-entities condition

Event I.D.	Date of Last Occurrence	Number of Days between Occurrences	
		Mean ($\bar{x}_i$)	Standard Deviation (s_i)
009	5-9	20.0	1.25
032	5-6	20.5	1.00
128	5-12	20.5	1.50
155	5-23	20.0	0.75
168	5-18	20.0	1.75

B. Data for the few-decision-entities condition

Uniform instructions were administered to all subjects regarding the general nature of the experiment and their participation (see Appendix D, P. 89). Special care was given to insure that subjects understood their objective in the game. A familiarization session consisting of five decision points (days) was conducted to acquaint subjects with their decision environment. These sessions were considered to be long enough to check subject "learning" effects during the experimental runs. In no case did data collection begin until subjects indicated that they felt comfortable with the procedure and ready to start.[1]

Three remote terminals were used for conducting the runs. Each was on line with a master program that mantained a file with the results of each run. The file included the three performance criteria and the scores of the post-experimental questionnaire.

3.3 Evaluation of Hypotheses

Table 3.3 (p. 41) shows the main effects and interactions that should be observed for the hypotheses to be supported. Each of these effects is discussed next.

Hypothesis 1. Information layout (factor A in table 3.1) should affect decision time such that the subjects with due-date ordered reports should have shorter decision times than those with I.D. ordered reports, i.e., $\bar{A}_2 < \bar{A}_1$: TIME. The due-date order should be more convenient given the chronological way in which the information is going to be used.

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[1]The average familiarization session took 15.2 minutes.

TABLE 3.3

EFFECTS PREDICTED BY THE RESEARCH HYPOTHESES

Hypothesis	Variant of Model of Section 2.7, p. 31	Experimental Variables	Measure	Effect
Main Effects				
H1	P = f(F|L,DE,DM,CIS')	P	Decision time	Subjects with due-date ordered reports should have shorter decision times than subjects with I.D. ordered reports.
		F	I.D. ordered vs. due-date ordered reports	
H2	P = f(F|L,DE,DM,CIS')	P	Number of Checks	Subjects with the graphical style should make more checks than subjects with the tabular style.
		F	Tabular vs. graphical reports	
H4	P = f(L|F,DE,DM,CIS')	P	Total cost	Subjects with interval estimates should have lower costs than subjects with point estimates.
		L	Point estimates vs. interval estimates	
Interactions				
H3	P = f(F|L,DE,DM,CIS')	P	Decision time	Subjects with I.D. ordered reports in graphical style should have shorter decision times than those with the I.D. ordered reports in tabular style.
		F	I.D. vs. due-date ordered reports, tabular vs. graphical reports	
H5	P = f(F,L|DE,DM,CIS')	P	Decision time	Subjects with interval estimates in graphical style should have shorter decision times than those with interval estimates in tabular style.
		F	Tabular vs. graphical reports	
		L	Point vs. interval estimates	
H6	P = f(F,DE|L,DM,CIS')	P	Decision time, total cost	The time and cost performance of subjects in the many-decision-entities group should be more sensitive to format than that of the subjects in the few-decision-entities group.
		F	I.D. vs. due-date ordered reports, tabular vs. graphical reports	
		DE	Many vs. few decision entities	

Hypothesis 2. The total number of chekcs made should be affected hy the style treatment (factor B). It is expected that the number of checks made by the graphical style users will be larger than that made by the tabular style users, i.e., $\bar{B}_2 > \bar{B}_1$: CHECKS, since the graphical style appears to illustrate the "choice space" more clearly, thus inviting more check decisions.

Hypothesis 3. Decision times of subjects receiving some combination of layout and style (A,B) should be significantly different from decision times of subjects receiving some other combination. Specifically it is expected that subjects receiving I.D. ordered reports and the graphical style will have shorter decision times than those receiving the I.D. ordered report but not the graphical style, i.e., $\overline{A_1B_2} < \overline{A_1B_1}$: TIME. The graphical style should reduce the need for the time-convenient due-date ordering.

Hypothesis 4. Subjects receiving the interval estimates should perform better than those receiving only point estimates, i.e., it is expected that $\bar{C}_2 < \bar{C}_1$: COST. The interval estimate subjects will have more information on the random nature of the events.

Hypothesis 5. Decision times of subjects receiving some combination of style and level of detail (B,C) should be significantly different from decision times of subjects receiving some other combination. In particular, it is expected that the subjects receiving interval estimates in the graphical style will have shorter decision times than those receiving the interval estimates in the tabular style, i.e., $\overline{B_2C_2} < \overline{B_1C_2}$: TIME. The graphical style should make it easier for users to process the interval estimates information.

Hypothesis 6. Differences in format opinion should be observed among the various layout and style treatments administered to the many-decision-entities subjects (D_1). Differences in both time and cost performance should also be observed among this group. This will indicate that report users have preference differences for format and their performance is more sensitive to format when the number of decision entities on their report is large. Non-significant differences should result among the same layout and style combinations administered to the few-decision-entities subjects (D_2). In general, it is expected that the opinion ratings will average higher for the few decision entities group, i.e., $\bar{D}_2 > \bar{D}_1$: RATINGS. Differences $\overline{A_1D_1} - \overline{A_2D_1}$, $\overline{B_1D_1} - \overline{B_2D_1}$ and $\overline{A_1B_1D_1} - \overline{A_1B_2D_1}$ are expected to be significant for cost, time and the opinion ratings. The same comparisons with D_2 instead of D_1 are not expected to be significant (the few-decision-entities case). The experimental results are presented in the next chapter.

CHAPTER 4

EXPERIMENTAL RESULTS

4.1 Introduction

The statistical results of the experiment are presented in this chapter. Table 4.1 (p. 45) shows the cell means obtained for the three performance variables and the five format opinion questions. The results revealed significant differences among treatment means to support five of the six research hypotheses.

4.2 Results

4.2.1 Effect of Layout on Decision Time

The first hypothesis, that information layout can reduce decision time, was supported. As Table 4.1 shows, decision time was shorter for the subjects receiving the due-date ordered reports, A_2, than for those receiving the I.D. ordered reports, A_1 (13.8 versus 16.4 minutes). A multivariate test on the three performance variables showed a significant layout main effect ($F = 7.41$, $p < .00001$).[1] A univariate test on the decision time variable also revealed a significant difference between the two layout groups ($\bar{A}_2 < \bar{A}_1$, $F = 13.35$, $p < .003$). A Scheffé post-hoc test revealed an even stronger relationship when

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[1] All multivariate F's presented here are based on 3 and 142 degrees of freedom. All the univariate F's are based on 1 and 144 degree of freedom.

TABLE 4.1

CELL MEANS FOR THE SIXTEEN EXPERIMENTAL CONDITIONS

	Many decision entities (D_1)								Few decision entities (D_2)							
	Tabular style (B_1)				Graphical style (B_2)				Tabular style (B_1)				Graphical style (B_2)			
	PE[b] (C_1)		IE (C_2)		PE (C_1)		IE (C_2)		PE (C_1)		IE (C_2)		PE (C_1)		IE (C_2)	
Dependent Variables	ID[c] (A_1)	DD (A_2)	ID (A_1)	DD (A_2)	ID (A_1)	DD (A_2)	ID (A_1)	DD (A_2)	ID (A_1)	DD (A_2)	ID (A_1)	DD (A_2)	ID (A_1)	DD (A_2)	ID (A_1)	DD (A_2)
1. Decision Time	23.8	17.6	29.5	19.6	23.0	21.2	22.8	20.0	7.7	7.6	7.0	8.4	8.5	7.1	8.7	8.8
2. Number of Checks	69.8	62.6	65.8	66.1	73.4	75.5	68.8	76.2	18.4	20.7	16.2	20.0	16.2	17.6	18.9	20.1
3. Total Cost	103.3	105.1	92.3	103.1	100.4	111.5	98.8	108.2	22.4	26.2	19.3	25.5	18.2	17.6	21.9	24.1
4. Layout[a]	2.9	3.8	1.7	4.5	3.2	3.6	3.5	4.0	3.2	3.5	3.3	4.2	3.6	4.0	4.1	4.1
5. Format (1)	3.5	3.3	2.6	4.0	3.2	3.9	3.2	3.1	3.4	3.2	4.2	3.8	3.2	3.9	4.4	4.1
6. Format (2)	3.8	3.7	3.4	4.6	3.8	4.0	4.1	3.8	4.0	3.8	3.8	4.5	3.5	4.4	4.6	4.1
7. Level of Detail	3.4	3.7	4.1	4.3	3.0	3.0	3.9	4.2	3.6	3.7	4.3	3.9	3.3	4.2	4.7	4.5
8. Over-all Format	3.8	3.6	2.8	4.5	3.5	3.6	3.5	3.9	3.7	3.9	4.3	4.2	3.4	4.2	4.3	4.2

Notes.

[a] Variables numbered 4 through 8 are the mean ratings for the format opinion questionnaire. These ratings are based on a five-choice scale: 1, 2, 3, 4, 5, with 1 indicating "very little" and 5 indicating "very much" liking.

[b] PE - point estimates; IE - interval estimates.

[c] ID - I.D. ordered reports; DD - due-date ordered reports.

only the many-decision-entities subjects, D_1, were considered. Within this group, the subjects receiving the due-date ordered reports had significantly shorter decision times ($\overline{A_2D_1} < \overline{A_1D_1}$, $F = 26.76$, $p < .00001$). No significant interactions were observed within the few-decision-entities group. In all the tests, decision time was significantly shorter for the subjects receiving the due-date ordered reports, thus supporting the hypothesis.

4.2.2 Influence of Format on Choice Behavior

The second hypothesis, that the format in which probabilistic information is presented can influence choice behavior, was supported. As Table 4.1 illustrates, the total number of checks made was higher for the subjects using the graphical style, B_2, as opposed to the tabular style, B_1. A multivariate test revealed a weak interaction between style and number of decision entities ($F = 2.60$, $p < .06$). Univariate tests on the number of checks variable showed a weaker style main effect ($\bar{B}_2 < \bar{B}_1$, $F = 3.38$, $p < .07$) and a stronger style and number of decision entities interaction ($F = 4.75$, $p < .03$). Within the many-decision-entities group, a Scheffé test revealed that the average number of checks was significantly higher for the graphical report users (73.5 versus 66.0, $F = 8.07$, $p < .005$). No significant differences were found in the number of checks made within the few-decision-entities group, and a comparison of the differences in the number of checks between the two styles subjects for the D_1 and D_2 groups was highly significant ($[B_2D_1 - B_1D_1] < [B_2D_2 - B_1D_2]$, $F = 131.83$, $p < .00001$). Presuming that the total number of checks made, regardless of success, was a reasonable measure of choice

behavior in this problem, the results support Conrath's [8] contention that presentation format influences choice behavior.

4.2.3 Joint Effect of Layout and Style Decision Time

The third hypothesis, that information layout and style can interact to reduce decision time, was supported. Table 4.1 shows that, within the many decision entities group, subjects using the I.D. ordered reports, A_1, had shorter decision times when they also received the graphical style, B_2. A multivariate test revealed a marginal interaction between style and number of decision entities ($F = 2.43$, $p < .08$). Univariate tests on the decision time variable showed a stronger ABD interaction ($F = 6.20$, $p < .02$). A Scheffé test revealed that the significance was due to the shorter decision times of the subjects receiving the I.D. ordered reports in graphical style ($\overline{A_1B_2D_1} < \overline{A_1B_1D_1}$, $F = 7.01$, $p < .009$). The fact that a significant layout and style interaction was observed only within the many-decision-entities group also supports H6: that performance[1] becomes more sensitive to format as the number of decision entities on the report increases. This is also demonstrated by the fact that, within the few-decision-entities group, both the layout main effect ($F \doteq 0$, $p \doteq 1$) and the interaction between layout and style ($F = .78$, $p > .35$) were not significant.

4.2.4 Effect of Probabilistic Detail on Cost Performance

The fourth hypothesis, that users of probabilistic data can make cost-effective use of information beyond point estimates, was not

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[1] Time performance in this case.

supported. Subjects receiving the interval estimates treatment, C_2, had lower costs than those receiving the point estimates, C_1, but the difference was not significant. The univariate level-of-detail main effect, with cost as the dependent variable, had $F = .34$, and the Scheffé test on $\overline{C_1D_1} - \overline{C_2D_1}$ was also non-significant ($F = 2.42$, $p > .10$). Contrary to the author's expectation, these results do not systematically support the hypothesis, though the directions are as predicted, nor do they support Conrath's [8] argument that decision makers do better with point estimates than with other probability measures.

4.2.5 Joint Effect of Format and Level of Detail on Decision Time

Support of the fifth hypothesis was weak. The hypothesis is that the format in which probabilistic data is presented interacts with the level of detail to influence the time required to process and use the information. The multivariate level-of-detail and style interaction was not significant ($F = 1.19$, $p > .25$). There was a significant univariate interaction between style, level of detail, and the number of decision entities on the report ($F = 3.70$, $p \doteq .05$). In particular, the many-decision-entities subjects, D_1, receiving interval estimates, C_2, in graphical style, B_2, had significantly shorter decision times than those receiving the same level of detail but in tabular style ($\overline{B_2C_2D_1} < \overline{B_1C_2D_1}$, $F = 4.95$, $p < .03$). This result suggests that certain formats may be better for reporting certain levels of probabilistic detail, but the absence of a significant multivariate effect makes the inference rather weak.

4.2.6 Relation between Number of Decision Entities and Format

The sixth hypothesis, that report users' preference for and sensitivity to format is related to the number of decision entities on their reports, was supported. Table 4.1 shows that subjects within the many-decision-entities group gave significantly different ratings to the various layout and style combinations. Two of the five opinion questions were used to verify that the subjects understood and systematically answered the post-experimental questionnaire (see Appendix B, p. 78). The validation consisted of checking that the ratings for these two questions were consistent with performance of subjects receiving the particular treatments mentioned in the questions:

(1) Question 1 asked the subjects to rate the order of the information in the reports. Table 4.1 shows that the subjects receiving the due-date ordered reports gave significantly higher ratings to this item than those receiving the I.D. ordered reports ($\bar{A}_2 > A_1$, $F = 17.33$, $p < .00004$).

(2) Question 4 asked the subjects to rate the level of probabilistic detail given. Table 4.1 illustrates that the subjects receiving the interval estimates consistently gave higher ratings to this item than those receiving the point estimates treatment ($\bar{C}_2 > \bar{C}_1$, $F = 18.86$, $p < .00002$).

In the case of Question 1, the many-decision-entities subjects gave significantly higher ratings to the due-date ordered reports ($\overline{A_2D_1} > \overline{A_1D_1}$, $F = 19.08$, $p < .12$). In Question 5, where the subjects were asked to give an over-all rating for the format of their reports, there was a significant difference in ratings between the many and few-decision-entities groups ($\bar{D}_2 > \bar{D}_1$, $F = 5.23$, $p < .03$).

With regard to the relationship between the number of decision entities and the sensitivity of performance to format, the discussion of the first five hypotheses has shown that the performance of the many-decision-entities subjects was more sensitive to format than that of the few-decision-entities subjects. In all the comparisons the differences in performance were larger among the many-decision-entities subjects than among the few-decision-entities subjects.

CHAPTER 5

DISCUSSION OF RESULTS

5.1 Summary of Findings

Tables 5.1, 5.2, and 5.3 (pp. 52 - 55) present a summary of the experimental results that had a significance level of $p < .10$ or better. The results have been grouped into main effects, interaction effects involving the number-of-decision-entities variable, and other interaction effects. In each case the actual significance figure has been given so that the reader can make his own judgement on the significance of each result. The hypotheses relating to each result are also shown in the right margin, along with a line reference number, to facilitate the discussion in the following sections.

The results are discussed first for the multivariate (MANOVA) effects. These do not relate to any hypothesis in particular, since the hypotheses have been stated in terms of the effect of the experimental treatments on specific criterion variables. They contain, however, important information about the total effect of the treatments on decision performance in general. The univariate effects are discussed next as they relate to each hypothesis. In each case, the implications for both the MIS researcher and practitioner are discussed.

5.2 The Multivariate Effects

Information layout (I.D. versus due-date ordering) was found to

TABLE 5.1

MAIN EFFECTS

Independent Variable	Dependent Variable	Level of Significance	Results	Related Hypotheses	Line No.
Information Layout	Decision Time, Cost, and Number of Checks Made	.00001	Information layout had a simultaneous effect on all three performance criteria.	—	5.1.1
Information Layout	Decision Time	.00026	Subjects with due-date ordered reports had shorter decision times than subjects with I.D. ordered reports.	H1	5.1.2
Style of Presentation	Number of Checks Made	.066	Subjects with graphical reports made more checks than subjects with tabular reports.	H2	5.1.3
Number of Decision Entities	Layout Rating	.060	Subjects with few decision events rated their report layout higher than subjects with many events.	H6	5.1.4
Information Layout	Layout Rating	.00003	Subjects with due-date ordered reports rated their layout higher than subjects with I.D. ordered reports.	H6	5.1.5
Number of Decision Entities	Level of Detail Rating	.060	Subjects with few decision events rated the detail of their reports higher than subjects with many decision events.	H6	5.1.6

TABLE 5.2

INTERACTION INVOLVING THE NUMBER-OF-DECISION ENTITIES-VARIABLES

Other Independent Variables	Dependent Variable	Level of Significance	Results	Related Hypotheses	Line No.
Information Layout	Decision Time, Cost, and Number of Checks Made	.0015	The effect of layout on general decision performance was stronger among the many decision entities group.	—	5.2.1
Information Layout	Decision Time	.00001	Subjects in the many-decision-entities group experienced larger decision time reductions when they were given the due-date order layout.	H1,H6	5.2.2
Style of Presentation	Decision Time, Cost, and Number of Checks Made	.062	Style and number of decision entities had a joint effect on the three performance criteria taken simultaneously.	—	5.2.3
Style of Presentation	Number of Checks Made	.029	The effect of style on number of checks made was stronger among the many decision entities group.	H2,H6	5.2.4
Information Layout and Style of Presentation	Decision Time, Cost, and Number of Checks Made	.074	Layout and style had a joint total effect on decision performance. The effect was stronger among the many decision entities group.	—	5.2.5

TABLE 5.2 (continued)

Other Independent Variables	Dependent Variable	Level of Significance	Results	Related Hypotheses	Line No.
Information Layout and Style of Presentation	Decision Time	.013	Subjects with many decision events and I.D. ordered reports had shorter decision times when they were also given the graphical style. The effect was not observed among the few-decision-entities group.	H3,H6	5.2.6
Style of Presentation and Level of Detail	Decision Time	.055	Many-decision-entities subjects receiving interval estimates in graphical style had shorter times than those receiving the same level of detail but in tabular style. The effect was not observed among the few-decision-entities group.	H5,H6	5.2.7
Information Layout	Layout Rating	.044	The many-decision-entities group gave the highest rating to the due-date layout. No significant differences in ratings were observed among the few-decision-entities group.	H6	5.2.8
Style of Presentation	Level of Detail Rating	.060	Subjects with many decision entities in tabular style rated the detail of their reports higher than subjects with the graphical style. No significant differences in ratings were observed among the few-decision-entities group.	H6	5.2.9

TABLE 5.3

OTHER INTERACTION EFFECTS

Independent Variable	Dependent Variable	Level of Significance	Results	Related Hypotheses	Line No.
Information Layout and Style of Presentation	Layout Rating	.016	Subjects with the I.D. layout rated it very low, except in the case of those that also had the graphical style.	H6	5.3.1
Information Layout, Style of Presentation, and Level of Detail	Layout Rating	.060	Ratings for the I.D. layout were specially lower from the point estimate subjects. The difference was not significant for those subjects who also received the graphical style.	H6	5.3.2
Information Layout, Style of Presentation, and Level of Detail	Format (1,2) Rating	.039,.DD4	Interval estimate subjects with the I.D. layout had low ratings, except in the case of those that also received the graphical style.	H6	5.3.3
Information Layout, Style of Presentation, and Level of Detail	Over-all Format Rating	.093	Same effect as above. The effect was more marked among the many-decision-entities group.	H6	5.3.4

affect decision performance in general (5.1.1).[1] Multivariate analysis is called for here since the performance criteria measured (decision time, cost, and number of checks made) are not independent. In the present study, the simultaneous effect of layout on the three performance criteria gives more value to the observed univariate effect on decision time. If Hypothesis 1 (p.28) had read "information layout can influence decision performance," it would have been equally supported. The fact that the effect observed was stronger among the many-decision-entities subjects (5.2.1) also lends support to Hypothesis 6 (p. 30).

The style of presentation (tabular versus graphical) was also seen to have a significant total effect on decision performance (5.2.3). Although the univariate effect of style on cost was not significant, the graphical style users within the many-decision-entities group had higher costs than the tabular style users ($104.73 versus $100.95, p = .258). This result contradicts Benbasat and Schroeder's [5] results, who observed that subjects with graphical reports had lower costs than those with tabular listings. Neither result, however, is significant (theirs had p = .148). This indicates that there is still no basis for predicting the effect of presentation style on cost performance. Either result could have been due to chance alone.

In terms of future MIS research, it is suggested here that MANOVA should be used in the analysis of experimental data. Winer [30, p. 232] explains that whenever there is reason to believe that dependent variables

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[1] The number in parenthesis is the reference to the related result in the tables.

are correlated, these should be considered simultaneously to obtain information about the "total" effect of the experimental variables. In the case of experimental MIS research, there is reason to believe that commonly used criteria, such as cost performance and decision time, are correlated [5, 9].

From the point of view of the MIS practitioner, these multivariate results point to one conclusion: the format in which information is presented can influence decision performance. The multivariate separate and joint effects of the two format variables in this study, layout and style, support this view. The specific directions of these effects are discussed next.

5.3 The Univariate Effects

5.3.1 Effects Related to H1 and H3

The influence of information layout on decision time was found to be strong (5.1.2), as predicted in Hypothesis 1 (p. 28). The shorter decision times for the subjects with due-date as opposed to I.D. ordered reports were expected, since the due-date ordering was more convenient in the present problem. This hypothesis, however, was evaluated for two reasons. The first was to demonstrate the importance of arranging the information in a manner consistent with the way information is used. This seemingly obvious observation appears to have been ignored in many reports this author has had to use. The second reason was to prepare a basis for Hypothesis 3 (p.29). There, it is proposed that long decision times due to an inconvenient information layout can be reduced by introducing a second format element, namely, the graphical style. The time dimension added by the graphical style had the effect of reducing the need for the

due-date ordering, while still maintaining a desirable feature of the report (the I.D. ordering of the events). This is evidenced by the result in Table 5.2, line 6.

These results have other implications, besides supporting H1 and H3. For the MIS researcher, they suggest the need for more investigation on the layout variable. It might be revealing example, to look at information layout schemes for information on events that are less time-dependent in nature than the ones studied here.[1] Maintenance data on some mechanical process, for example, could provide a setting for an interesting and practical experiment.

To the MIS practitioner, and in particular to the person in charge of designing information formats, the results emphasize the importance of reporting information in a manner consistent with the way recipients use it. Also, the observed interaction between layout and style suggests that practitioners should be on the alert for joint effects among format elements that can work to their advantage in enhancing the readability of the report.

5.3.2 Effects Related to H2

Perhaps most striking was the result that subjects with graphical reports chose to make substantially more "checks" than subjects with tabular reports (5.1.3). This supports Hypothesis 2 (p. 28), namely, that the format in which probabilistic information is presented can influence choice. From a research point of view, a question that remains to be answered is

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[1] All events in this world are probably time dependent, but their occurrence may be more dependent on time for some types (e.g., biological) than for others (e.g., electrical components).

whether the observed effect was related to the short duration of the experiment, or whether the effect would have continued even if the subjects had been given enough time to get fully acquainted with their report style. In either case, the result observed here is an important finding since many real-life managerial reports have short-term use, are "one-shot-non-recurrent" reports, and, very frequently, contain information of a probabilistic nature. Ergo, the information analyst that must report probabilistic information as a basis for decisions appears to have a delicate problem at hand: if the format in which he presents the information is going to bias the choice of the decision maker, he will surely want that bias to be in the "correct" direction. This point is also related to the issue of normative versus descriptive reports, and is a point that should be further investigated elsewhere.

5.3.3 Effects Related to H5

A result closely related to the preceding discussion provided support for Hypothesis 5 (p. 30; 5.2.7). Within the many-decision entities group, the subjects with interval estimates had shorter decision times when the information was given to them in graphical as opposed to tabular style (21.4 versus 24.6 minutes, $p = .026$). Point estimates users, however, did not experience the same benefits in moving from the tabular to the graphical style. Their average decision time, in fact, was higher with the graphical style than with the tabular style (22.1 versus 20.7 minutes, $p = .32$). These results suggest that different levels of probabilistic information may be more appropriately reported using different presentation formats. In the present experiment, subjects with the tabular style did as good or better than subjects with the graphical

style when only point estimates were reported. The compact tabular format was inadequate, however, for processing the interval estimates information.

5.3.4 Effects Related to H6

All the effects that have been discussed thus far were found to be more marked within the many-decision-entities group (5.2.2, 5.2.4, 5.2.6, 5.2.7). This supports one of the propositions in Hypothesis 6, (p. 30), that user performance becomes more sensitive to report format as the number of decision entities on the report increases. In the present experiment, the subjects with five decision entities on their reports had so little information to process that whether it was given in I.D. order, due-date order, tabular style or graphical style did not make much difference on their performance. Evidence of this is that, within the five decision events group, there were no significant differences in performance for any of the performance measures. The only effect that approached significance in that group was an interaction between style and level of detail with cost as the dependent variable ($p < .10$).

The other proposition in H6, that report users will move from indifference to preference for particular formats as the number of decision entities increases, was also supported. The subjects in the few-decision-entities group gave more or less constant high ratings to the various format characteristics of their reports (5.2.8, 5.2.9). Within that group, there were no significant differences in the ratings for the order of the information in the reports (layout). For the over-all format rating, only one difference was significant. Interval estimate subjects gave significantly higher ratings than point estimate subjcets (4.25 versus 3.80, $p = .044$). Among the subjects with twenty-five decision

entities, the story was quite different (5.2.8, 5.2.9, 5.3.3, 5.3.4). There were significant differences between their ratings in the various layout and style conditions.

For the MIS practitioner, these results suggest that they should give careful attention to report format, especially when the report must grow. The results obtained here give meaning to Voich, et al.'s statement, "As the complexity of a report increases, its likelihood of extent of use falls" [28, p. 229]. When preparing a report for a procurement manager, for example, a standard layout by major classes of items, code number, etc., may be appropriate if the number of items that must be ordered each time, and their frequencies of ordering, are small. If the number of orders that must be placed were to increase considerably, it may be to the manager's advantage to have the layout of his report revised. A more favorable layout in that case could be, for example, to have the items arranged according to the frequency with which they are ordered.

For format revisions or similar actions to occur, the channels of communication between the information analyst and user must first be improved. At the present, there appears to be a "tail versus dog" problem between information users and providers when it comes to seemingly unimportant matters, such as designing a format for a report. Voich et al. state:

> Report formats are often not tailored precisely to users' needs. One reason for this is the programming costs associated with special arrangements of information, especially if several different users each request a unique format. A second reason for finding formats not tailored exactly to user's needs is that report designs are often based on

> the system analysts' or programmers' preferences for programming ease [28, p. 229].

It would appear that better communication channels between the analyst and the user should, at least, help to alleviate the second reason noted above.

CHAPTER 6

SUMMARY AND POSSIBLE EXTENSIONS

The present study has considered some of the implications of the relationship between information format and decision performance. A specific information-decision problem was abstracted to create a simulated decision environment within which alternative forms of presenting information relevant to the problem were experimentally manipulated. Six hypotheses were tested in relation to the effects of the information format treatments on subject performance. The experimental data supported five of the six hypotheses. As is always the case with empirical research, however, a number of questions can be raised in connection with the observed results. Some questions result from inquiring into the limitations of the present study. Others follow logically from the results.

Among the limitations, there is the problem of having used student subjects as surrogates for managers [13]. The actual managers in the real-life problem modeled could have served as subjects in a field study. This, of course, may bring about other complications, in particular, problems of experimental control. Van Horn states:

> The unifying theme of field tests is sad stories. In every one, operational considerations (understandably) dominate test conditions. As soon as a conflict arises, the test yields. Even if a test proceeds to completion, endless arguments arise over interpretation of the results [28, p. 175].

Going to the field also implies having to deal with uncooperative mother nature, as opposed to pre-chosen probability distributions for the events of interest. Notwithstanding this dismal picture, a field experiment should be useful. By establishing the external validity of the present study with respect to the subject population, decision-making conditions, and other areas of interest, its benefit for the actual population can be established and considered in the design of a field study. A practical field study could be, for example, one in which a more normative report is provided to the manager facing the heat detection problem. Such a report could be based on some optimal decision rule indicating to the dairyman the days in which he should check for heat in particular cows. The decision rule would have to be based on some cost estimates (costs of "checking," "missing," and breeding after a succesful "check"), and on some probability estimates (probability of detecting heat on given "checks," probability of a succesful breeding once heat is detected, etc.).

Although growing fast, "experimental work on MIS is still in its infancy" [5, p. 17]. Many promising areas have not been investigated. One line of research that follows from the present results is the relationship between the number of decision entities in the report and the sensitivity of performance to format variables. Various number-of-decision-entities levels could be manipulated in a parametric study to investigate such questions as, "Can a report user adapt to an increasing number of decision entities in his report without a rapid deterioration in his performance?" To investigate this question the same subjects would have to be given increasing numbers of decision entities, and this could bring up problems of subject "learning." If properly controlled, however, an experiment along these lines could

shed light into such questions as, "At what point would it have been appropriate to have a format revision?"

Another area that appears to need more consideration is the analysis of interaction effects among information structure characteristics [5, 12]. In this study, an interaction was found between the level of detail and format, suggesting that different levels of detail may be more easily processed with different styles of presentation. The validity of findings such as this one should be further investigated in other decision contexts. Finally, research relating empirical MIS findings to current trends in the theory of human information processing may be useful in providing a better understanding of the results observed.

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APPENDIX A

EXPERIMENTAL TREATMENTS

The sixteen reports that constituted the experimental treatments are shown here in the same size they were administered to the subjects. The only difference between these reports and those used by the subjects is that the latter had horizontal green lines across them to facilitate their use. Each report is labeled with the "condition" numbers used in Table 3.1 (p. 35).

EVENT IDENT.	EXPECTED DUE-DATE (MONTH-DAY)
004	6-07
009	5-29
017	6-11
024	6-04
032	5-26
038	6-04
051	5-31
070	6-01
076	6-10
078	5-30
082	6-03
085	6-10
097	6-05
110	6-11
121	6-05
128	6-01
142	6-09
146	5-28
155	6-12
163	6-09
168	6-07
171	5-31
173	6-06
177	6-06
186	5-31

Condition 1

EVENT IDENT.	EXPECTED DUE-DATE (MONTH-DAY)
032	5-26
146	5-28
009	5-29
078	5-30
171	5-31
051	5-31
186	5-31
070	6-01
128	6-01
082	6-03
024	6-04
038	6-04
121	6-05
097	6-05
173	6-06
177	6-06
168	6-07
004	6-07
163	6-09
142	6-09
085	6-10
076	6-10
110	6-11
017	6-11
155	6-12

Condition 2

EVENT IDENT.	95% CONFIDENCE INTERVAL (FIRST DAY, LAST DAY)
004	6-06 , 6-09
009	5-27 , 5-31
017	6-10 , 6-12
024	6-01 , 6-07
032	5-25 , 5-28
038	6-02 , 6-06
051	5-29 , 6-03
070	5-31 , 6-02
076	6-09 , 6-12
078	5-27 , 6-02
082	6-01 , 6-05
085	6-09 , 6-14
097	6-04 , 6-07
110	6-10 , 6-12
121	6-03 , 6-07
128	5-30 , 6-04
142	6-06 , 6-12
146	5-26 , 5-30
155	6-11 , 6-13
163	6-07 , 6-12
168	6-04 , 6-10
171	5-28 , 6-03
173	6-05 , 6-07
177	6-05 , 6-08
186	5-29 , 6-03

Condition 3

EVENT IDENT.	95% CONFIDENCE INTERVAL (FIRST DAY, LAST DAY)
032	5-25 , 5-28
146	5-26 , 5-30
009	5-27 , 5-31
078	5-27 , 6-02
171	5-28 , 6-03
051	5-29 , 6-03
186	5-29 , 6-03
128	5-30 , 6-04
070	5-31 , 6-02
082	6-01 , 6-05
024	6-01 , 6-07
038	6-02 , 6-06
121	6-03 , 6-07
168	6-04 , 6-10
097	6-04 , 6-07
173	6-05 , 6-07
177	6-05 , 6-08
004	6-06 , 6-09
142	6-06 , 6-12
163	6-07 , 6-12
085	6-09 , 6-14
076	6-09 , 6-12
110	6-10 , 6-12
017	6-10 , 6-12
155	6-11 , 6-13

Condition 4

EXPECTED OUE-OATES

EVENT IDENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IOENT.
004														H							004
009					H																009
017																		H			017
024											H										024
032		H																			032
038											H										038
051							H														051
070								H													070
076																	H				076
078						H															078
082										H											082
085																	H				085
097												H									097
110																		H			110
121												H									121
128								H													128
142																H					142
146				H																	146
155																			H		155
163																H					163
168														H							168
171							H														171
173													H								173
177													H								177
186							H														186
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Condition 5

EXPECTED DUE-OATES

EVENT IOENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IOENT.
032		H																			032
146				H																	146
009					H																009
078						H															078
171							H														171
051							H														051
186							H														186
070								H													070
128								H													128
082										H											082
024											H										024
038											H										038
121												H									121
097												H									097
173													H								173
177													H								177
168														H							168
004														H							004
163																H					163
142																H					142
085																	H				085
076																	H				076
110																		H			110
017																		H			017
155																			H		155
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Condition 6

95% CONFIDENCE INTERVALS

EVENT IDENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IDENT.
004													H	H	H	H					004
009			H	H	H	H	H														009
017																	H	H	H		017
024								H	H	H	H	H	H	H							024
032	H	H	H	H																	032
038									H	H	H	H	H								038
051					H	H	H	H	H	H											051
070							H	H	H												070
076																H	H	H	H		076
078			H	H	H	H	H	H	H												078
082								H	H	H	H	H									082
085																H	H	H	H	H	085
097											H	H	H	H							097
110																	H	H	H		110
121										H	H	H	H	H							121
128						H	H	H	H	H	H										128
142													H	H	H	H	H	H	H		142
146		H	H	H	H	H															146
155																		H	H	H	155
163														H	H	H	H	H	H		163
168											H	H	H	H	H	H	H				168
171				H	H	H	H	H	H	H											171
173												H	H	H							173
177												H	H	H	H						177
186					H	H	H	H	H	H											186
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Condition 7

95% CONFIDENCE INTERVALS

EVENT IDENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IDENT.
032	H	H	H	H																	032
146		H	H	H	H	H															146
009			H	H	H	H	H														009
078			H	H	H	H	H	H	H												078
171				H	H	H	H	H	H	H											171
051					H	H	H	H	H	H											051
186					H	H	H	H	H	H											186
128						H	H	H	H	H	H										128
070							H	H	H												070
082								H	H	H	H	H									082
024								H	H	H	H	H	H	H							024
038									H	H	H	H	H								038
121										H	H	H	H	H							121
097											H	H	H	H							097
168											H	H	H	H	H	H	H				168
177												H	H	H	H						177
173												H	H	H							173
004													H	H	H	H					004
142													H	H	H	H	H	H	H		142
163														H	H	H	H	H	H		163
076																H	H	H	H		076
085																H	H	H	H	H	085
110																	H	H	H		110
017																	H	H	H		017
155																		H	H	H	155
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Condition 8

EVENT IDENT.	EXPECTED OUE-DATE (MONTH-DAY)
009	5-29
032	5-26
128	6-01
155	6-12
168	6-07

Condition 9

EVENT IOENT.	EXPECTEO OUE-OATE (MONTH-DAY)
032	5-26
009	5-29
128	6-01
168	6-07
155	6-12

Condition 10

EVENT IOENT.	95% CONFIOENCE INTERVAL (FIRST OAY, LAST OAY)
009	5-27 , 5-31
032	5-25 , 5-28
128	5-30 , 6-04
155	6-11 , 6-13
168	6-04 , 6-10

Condition 11

EVENT IDENT.	95% CONFIDENCE INTERVAL (FIRST OAY, LAST DAY)
032	5-25 , 5-28
009	5-27 , 5-31
128	5-30 , 6-04
168	6-04 , 6-10
155	6-11 , 6-13

Condition 12

EXPECTEO OUE-DATES

EVENT IOENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IOENT.
009					H																009
032		H																			032
128								H													128
155																			H		155
168														H							168
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Condition 13

EXPECTED DUE-DATES

EVENT IDENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IDENT.
032		H																			032
009					H																009
128								H													128
168														H							168
155																			H		155
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Condition 14

95% CONFIDENCE INTERVALS

EVENT IDENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IDENT.
009			H	H	H	H	H														009
032	H	H	H	H																	032
128						H	H	H	H	H	H										128
155																		H	H	H	155
168											H	H	H	H	H	H	H				168
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Condition 15

95% CONFIDENCE INTERVALS

EVENT IDENT.	MAY 25	26	27	28	29	30	31	JUNE 01	02	03	04	05	06	07	08	09	10	11	12	13	EVENT IDENT.
032	H	H	H	H																	032
009			H	H	H	H	H														009
128						H	H	H	H	H	H										128
168											H	H	H	H	H	H	H				168
155																		H	H	H	155
	25	26	27	28	29	30	31	01	02	03	04	05	06	07	08	09	10	11	12	13	

Condition 16

APPENDIX B

FORMAT OPINION QUESTIONNAIRE

The post-experimental questionnaire is presented here in an English version of the actual questions (shown toward the end of the program in Appendix C). A connotative rather than literal translation has been attempted to give the non-Spanish reader a more accurate representation of the content.

Please answer the following questions by entering a 1, 2, 3, 4, or 5, and pressing the "return" key. An entry close to 1 will indicate "very little" and an entry close to 5 will indicate "very much," as follows:

VERY LITTLE : 1 : 2 : 3 : 4 : 5 : VERY MUCH

1. How appropriate did you considered the order of the information in the report, given the type of decisions that had to be made?_____

2. How appropriate did you considered the format of the report at the time of making the daily decisions? _____

3. How appropriate did you considered the format of the report at the time of recording the feedback on events checked and detected? _____

4. How appropriate did you considered the detail of the probabilistic information on the possible date of occurrence of each event? _____

5. All factors considered, how appropriate did you considered the format of your report? _____

APPENOIX C

COMPUTER SIMULATION PROGRAM

A.1 General

This program created the simulated decision environment for the experimental runs. The program was written in BASIC, Version 17, Digital Equipment Corporation System 10. It was run from a typewriter terminal, model OEC 33 TELETYPE, on line with a PDP 10.

A.2 Input

The fixed input to the program was the data of Table 3.2, (p. 39) arranged as follows:

E$(J)	M	D	I	S
004	5	18	20.5	1.00
009	5	9	20.0	1.25
017	5	22	20.0	0.75
024	5	15	20.0	1.75
032	5	6	20.5	1.00
038	5	15	20.0	1.25
051	5	11	20.5	1.50
070	5	12	20.0	0.75
076	5	21	20.5	1.00
078	5	10	20.0	1.75
082	5	14	20.0	1.25
085	5	21	20.5	1.50
097	5	16	20.5	1.00
110	5	22	20.0	0.75
121	5	16	20.0	1.25
128	5	12	20.5	1.50
142	5	20	20.0	1.75
146	5	8	20.0	1.25
155	5	23	20.0	0.75
163	5	20	20.5	1.50

E$(J)	M	D	I	S
168	5	18	20.0	1.75
171	5	11	20.0	1.75
173	5	17	20.0	0.75
177	5	17	20.5	1.00
186	5	11	20.5	1.50

where E&(J) = event I.D. number

M = month of last occurrence

D = day of last occurrence

I = mean interval between occurrences

S = standard deviation of interval between occurrences

All other input to the program was manually entered by the subjects. It consisted of the I.D. numbers of the events they checked on each successive day, and the answers to the post-experimental questionnaire.

A.3 Output

A sample of the beginning of a run is illustrated in Figure A.1 (p. 82). It shows an identification of the experimental report used in the run, the initial time clocked after the subject indicated he was ready to start,* and some of the outcomes of the early part of the run.

Figure A.2 (p. 83) is a sample from the last part of the experiment. It shows some of the last decisions made by the subject, the final decision time clocked (26 minutes and 3 seconds in the sample shown), the summarized results of the run, and the post-experimental questionnaire with the subject's answers. The last two lines seen are part of the file updated with the results of each run. The program is on pp. 84-88.

*A pre-experimental familiarization session had already been conducted.

```
SUBJECT IS USING REPORT 3.

TI TODAY: ?18:06 [illegible]: 5.60 [illegible]:137 WA:62 BASIC 16P+C5P TI SV PC:#14765


TODAY IS 5-25
-------------
CHECKS ?
 ?032
CHECKED: 032      DETECTED: NONE

TODAY IS 5-26
-------------
CHECKS ?
 ?032 146
CHECKED:  032 146      DETECTED: NONE

TODAY IS 5-27
-------------
CHECKS ?
 ?032
CHECKED:  032      DETECTED:  032

TODAY IS 5-28
-------------
CHECKS ?
 ?009 146
CHECKED:  009 146      DETECTED: NONE
```

Figure A.1 Sample output at the beginning of a run

```
TODAY IS 6-1?
-------------
CHECKS ?
?017 095 110 142 155
CHECKED:  017 095 110 142 155      DETECTED:  110


TODAY IS 6-13
-------------
CHECKS ?
?095 155
CHECKED:  095 155      DETECTED:  155

***********
*******...FAVOR DE LLAMAR AL PROF. [illegible]....*******
TDAY: *06:03 RUN: 1.50 PD:0 [illegible]:0 BASIC [illegible] TI,[illegible] PC:414765
??


********* SUMMARY OF RESULTS FOR THE RUN ********

 59 CHECKS @ $1/CHECK = $59
 7 MISSES @ $5/MISS = $35

TOTAL COST = $94

ACTUAL EVENT DATES
------------------
EVENT ID.  DATE
---------  -------
```

EVENT ID.	DATE
004	6-7
009	5-30
017	6-9
024	6-4
032	5-27
038	6-4
051	6-1
070	5-31
076	6-12
075	5-30
082	6-2
085	6-10
097	6-5
110	6-12
121	6-5
128	6-2
142	6-6
146	5-29
155	6-13
163	6-10
168	5-9
171	5-29
173	6-6
177	6-6
186	5-31

```
REVISE ESTE RESUMEN DE RESULTADOS PARA VERIFICAR QUE LA INFORMACION
EN CUANTO A EVENTOS COTEJADOS Y DETECTADOS ES CORRECTA.  UNA VEZ HECHO
ESTO, OPRIMA 'RETURN'.
 ?

FAVOR DE CONTESTAR LAS SIGUIENTES PREGUNTAS ESCRIBIENDO UN '1','2','3',
'4' O '5' Y OPRIMIENDO LA TECLA 'RETURN'.  UNA RESPUESTA CERCA DE '1'
INDICARA 'POCO APROPRIADO' Y UNA RESPUESTA CERCA DE '5' INDICARA 'MUY
APROPRIADO', COMO SIGUE:

         POCO APROPRIADO : 1 : 2 : 3 : 4 : 5 : MUY APROPRIADO
                           --- --- --- --- ---

1.  CUAN APROPRIADO ENCONTRO USTED EL ORDEN DE LA INFORMACION
    EN EL REPORTE PARA EL TIPO DE DECISIONES QUE SE DEBIAN TOMAR ?2

2.  CUAN APROPRIADO FUE EL FORMATO DE PRESENTACION DEL REPORTE
    AL MOMENTO DE TOMAR LAS DECISIONES DIARIAS ?3

3.  CUAN APROPRIADO FUE EL FORMATO DEL REPORTE AL MOMENTO DE ANOTAR
    LA INFORMACION SOBRE LOS EVENTOS COTEJADOS Y DETECTADOS ?4

4.  CUAN APROPRIADO FUE EL DETALLE DE LA INFORMACION PROBABILISTICA
    SOBRE LA POSIBLE FECHA DE OCURRENCIA DE CADA EVENTO ?3

5.  CONSIDERANDO TODOS LOS FACTORES, COMO DE APROPRIADO ENCONTRO USTED
    EL FORMATO DE ESTE REPORTE ?3

**** [illegible] CONCLUIDO EL EXPERIMENTO... GRACIAS POR SU COOPERACION! ****
 5  ?  ?  ??  ?  3

1?3 ?? ?6 ?? ? 0?4 ? ? 4 ? 3
```

Figure A.2 Sample output at the end of a run

```
00005 REM ************************************************************
00010 REM *** INTERACTIVE SIMULATION OF THE EVENT CHECKING PROBLEM ***
00015 REM ************************************************************
00020 OIM A$(25),E$(25)
00030 FILES A1%,A2%,A3%,A4%,A5%,AO%,OATA,TALYA$
00035 DO=25
00040 PRINT "SO,R";
00050 INPUT SO,R
00060 IF R =8 THEN 70
00062 OO=5
00064 FOR J=1 TO 25.
00066 INPUT #7, NO,E$(J),M,D,I,S
00068 NEXT J
00070 C1=1
00075 PRINT
00080 C2=5
00090 PRINT
001DD PRINT "SUBJECT IS USING REPORT ";STR$(R)+"."
00105 PRINT
00110 FOR J=1 TO DO
00125 RO=O
00130 INPUT #7, NO,E$(J),M,D,I,S
00140 S$=S$+E$(J)
0021D RANDOMIZE
00220 FOR N=1 TO 12
00230 RO=RO+RND
00240 NEXT N
00250 Y=S*(RO-6) + I
00260 X=INT(Y+.5)
00280 IF (D+X) 31 GO TO 310
00290 D=O+X
00300 GO TO 330
00310 O=O+X-31
00320 M=M+1
00330 A$(J) = STR$(M)+"-"+STR$(D)
0034D NEXT J
00350 PRINT
00360 M=5
00370 O=24
00380 PRINT "T1";
0D381 INPUT T1$
00389 PRINT
00390 FOR I=1 TO 20
00400 D=O+1
00410 IF D 32 GO TO 440
00420 O=1
00430 M=M+1
00440 O$=STR$(M)+"-"+STR$(D)
00442 PRINT
00450 PRINT "TOOAY IS ";D$
00460 PRINT "-------------"
```

```
00470 PRINT "CHECKS ?"
00480 INPUT E$
00482 IF E$=" " THEN 630
00485 E$=E$+"AAAA."
00490 L=INSTR(E$,".")/4-1
00502 IF A8S(L-INT(L)) = 0 THEN 510
00504 GOSUB 2000
00506 GO TO 480
00510 FOR K=1 TO L
00520 Y=4*K-3
00525 Z=4*K-1
00530 K$=MID$(E$,Y,Z-Y+1)
00550 J=(INSTR(S$,K$)+2)/3
00560 C$=C$+E$(J)+" "
00570 C=C+1
00580 IF A$(J)  D$ THEN 610
00590 O$=O$+E$(J)+" "
00600 O=O+1
00610 NEXT K
00620 IF L =1 THEN 660
00630 PRINT "CHECKED: NONE"
00640 PRINT
00650 GO TO 730
00660 PRINT "CHECKEO: ";C$;
00670 IF LEN(O$) 1 THEN 690
00680 O$="NONE"
00690 PRINT "    OETECTEO: ";O$
00700 PRINT
00710 C$=" "
00720 O$=" "
00730 NEXT I
00735 PRINT "***********"
00740 PRINT "******...FAVOR DE LLAMAR AL PROF. AMAOOR....*******"
00751 INPUT T2$
00752 IF LEN(T2$) 1 THEN 754
00753 T2$="O"+T2$
00754 PRINT
00756 PRINT
00760 PRINT "******** SUMMARY OF RESULTS FOR THE RUN ********"
00770 PRINT
00780 PRINT C;"CHECKS @ $";STR$(C1)+"/"+"CHECK = $";STR$(C*C1)
00782 C8$=STR$(C)
00783 IF LEN(C8$) 2 THEN 790
00784 IF LEN(C8$) 1 THEN 788
00785 C8$="OO"+C8$
00786 GO TO 790
00788 C8$="O"+C8$
00790 PRINT DO-O;"MISSES @ $";STR$(C2)+"/"+"MISS = $";STR$((DO-O)*C2)
00795 PRINT
00800 PRINT "TOTAL COST = $"+STR$(C*C1+(DO-O)*C2)
00802 T8$=STR$(C*C1+(OO-O)*C2)
```

```
00804 IF LEN(T8$) 2 THEN 870
00806 T8$="0"+T8$
00870 PRINT
00880 PRINT "ACTUAL EVENT OATES"
00890 PRINT "------------------"
00900 PRINT "EVENT IO.  OATE"
00910 PRINT "--------- -------"
00920 FOR J=1 TO D0
00930 PRINT TAB(3);E$(J);TAB(11);A$(J)
00940 NEXT J
00950 PRINT
00960 PRINT "REVISE ESTE RESUMEN OE RESULTADOS PARA VERIFICAR"
00965 PRINT "QUE LA INFORMACION EN CUANTO A EVENTOS COTEJAOOS"
00970 PRINT "Y OETECTAOOS ES CORRECTA.  UNA VEZ HECHO ESTO,"
00975 PRINT "OPRIMA 'RETURN'."
01010 INPUT R9$
01020 PRINT
01030 PRINT "FAVOR DE CONTESTAR LAS SIGUIENTES PREGUNTAS ESCRI8IENOO UN"
01040 PRINT "1, 2, 3, 4, O 5, Y OPRIMIENDO LA TECLA 'RETURN'.  UNA"
01045 PRINT "RESPUESTA CERCA DE 1 INOICARA 'POCO APROPRIAOO'; UNA"
01050 PRINT "RESPUESTA CERCA DE 5 INDICARA 'MUY APROPRIADO, COMO SIGUE:"
01070 PRINT
01080 PRINT
01090 PRINT "         POCO APROPRIAOO : 1 : 2 : 3 : 4 : 5 : MUY APROPRIAOO"
01100 PRINT "                           --- --- --- --- ---"
01110 PRINT
01120 PRINT
01130 PRINT "1.  CUAN APROPRIADO ENCONTRO USTEO EL OROEN DE LA INFORMACION"
01140 PRINT "    EN EL REPORTE PARA EL TIPO DE DECISIONES QUE SE"
01145 PRINT "    OE8IAN TOMAR?"
01150 INPUT A1
01152 IF A1 5 THEN 1154
01153 IF A1 =1 THEN 1160
01154 GOSU8 2000
01156 GO TO 1150
01160 SET :1, R; :2, R; :3, R; :4, R; :5, R; :6, R
01162 INPUT :6, Q0
01164 Q0=Q0+1
01170 INPUT :1, C1
011B0 C1=C1+A1
01210 PRINT
01220 PRINT "2.  CUAN APROPRIADO FUE EL FORMATO DE PRESENTACION DEL REPORTE"
01230 PRINT "    AL MOMENTO OE TOMAR LAS OECISIONES DIARIAS?"
01240 INPUT A2
01242 IF A2 5 THEN 1244
01243 IF A2 =1 THEN 1250
01244 GOSU8 2000
01246 GO TO 1240
01250 INPUT :2, C2
01260 C2=C2+A2
01290 PRINT
```

```
01300 PRINT "3.  CUAN APROPRIAOO FUE EL FORMATO DEL REPORTE AL MOMENTO"
01305 PRINT "    DE ANOTAR LA INFORMACION SOBRE LOS EVENTOS COTEJADOS"
01310 PRINT "    Y OETECTAOOS?"
01320 INPUT A3
01322 IF A3 5 THEN 1324
01323 IF A3 =1 THEN 1330
01324 GOSUB 2000
01326 GO TO 1320
01330 INPUT :3, C3
01340 C3=C3+A3
01370 PRINT
013B0 PRINT "4.  CUAN APROPRIADO FUE EL DETALLE OE LA INFORMACION"
01385 PRINT "    PROBABILISTICA SOBRE LA POSIBLE FECHA OE OCURRENCIA"
01390 PRINT "    OE CADA EVENTO?"
01400 INPUT A4
01402 IF A4 5 THEN 1404
01403 IF A4 =1 THEN 1410
01404 GOSUB 2D00
01406 GO TO 140D
01410 INPUT :4, C4
01420 C4=C4+A4
01450 PRINT
01460 PRINT "5.  CONSIOERANOO TOOOS LOS FACTORES, COMO OE APROPRIADO"
01465 PRINT "    ENCONTRO USTED EL FORMATO DE ESTE REPORTE?"
01480 INPUT A5
01482 IF A5 5 THEN 1484
01483 IF A5 =1 THEN 1490
01484 GOSUB 2000
01486 GO TO 1480
01490 INPUT :5, C5
015D0 C5=C5+A5
01530 PRINT
01540 PRINT "........HEMOS CONCLUIOO EL EXPERIMENTO ....."
01545 PRINT "          ..... GRACIAS POR SU COOPERACION....."
01550 R8$=STR$(R)
01552 IF LEN(R8$) 1 THEN 1560
01554 R8$="0"+R8$
01560 Q8$=" "+STR$(A1)+" "+STR$(A2)+" "+STR$(A3)+" "+STR$(A4)+" "+STR$(A5)
01561 S0$=STR$(S0)
01562 IF LEN(S0$) 2 THEN 1570
01563 IF LEN(S0$) 1 THEN 1566
01564 S0$="0D"+SD$
01565 GO TO 1570
01566 S0$="0"+S0$
01570 T0$=S0$+" "+R8$+" "+T2$+" "+C8$+" "+T8$+Q8$
01600 SET :1,R; :2,R; :3,R; :4,R; :5,R; :6,R
D1610 WRITE :1,C1
01620 WRITE :2,C2
01630 WRITE :3,C3
01640 WRITE :4,C4
01650 WRITE :5,C5
```

```
01660 WRITE :6,Q0
01670 PRINT C1;C2;C3;C4;C5;Q0
01672 PRINT
01674 PRINT T0$
01680 SET :8,S0
01685 WRITE :8,T0$
01690 GO TO 2050
02000 PRINT
02005 PRINT "? INPUT DATA NOT IN CORRECT FORM--PLEASE RETYPE"
02010 RETURN
02050 END
```

APPENDIX D

SUBJECT INSTRUCTIONS

The written instructions given to the experimental subjects are shown here in their original version (in Spanish) and in an English version. Again, an effort has been made to present a connotative rather than literal translation so the non-Spanish reader can have a more accurate picture of their content. The statement of consent that was signed by each subject is also included.

Instrucciones

Introducción

Con este experimento se quiere medir la efectividad de un informe gerencial. El informe estudiado ha sido diseñado para ayudar a un gerente a "detectar" una serie de eventos de interés que han de ocurrir en el futuro próximo. La razón que amerita el uso de un informe en este caso es que estos eventos de interés ocurren al azar solamente durante el término de un día y luego no vuelven a ocurrir hasta después de aproximadamente 20 días. Es conveniente para la gerencia "detectar" el día en que estos eventos ocurren ya que se incurre en un costo de oportunidad cada vez que uno de estos eventos sucede y pasa sin ser detectado (la próxima oportunidad de observar el evento no vuelve a ocurrir hasta después de aproximadamente 20 días). El informe estudiado es preparado en base a estadísticas pasadas y consiste precisamente de las fechas más probables de ocurrencia para cada uno de una serie de estos eventos. El formato general de este informe es como sigue:

Identificación del Evento	Posible Fecha de Ocurrencia

En este experimento se quiere medir el efecto del formato de presentación de este informe sobre el uso efectivo que se le ha de dar al mismo. Usted recibirá uno de varios formatos experimentales de este informe y durante un período simulado de 20 días usted utilizará dicho informe para tratar de "detectar" una serie de eventos que según su informe han sido identificados como que han de ocurrir durante esos 20 días.

Reglas de la Simulación

Durante el experimento usted jugará el papel de un gerente que debe decidir a diario cuántos y cuáles "eventos" cotejar para ver si están "ocurriendo" en ese día o no. Las características del problema que usted deberá mantener en mente son las siguientes:

1. Usted recibirá un informe experimental con los "eventos" que deben ser "cotejados" durante los próximos 20 días. Estos eventos estarán identificados al lado izquierdo del

informe con un número de identificación de tres (3) dígitos. Al lado derecho del número de identificación de cada evento usted hallará información sobre la posible fecha de ocurrencia de ese evento.

2. Los eventos han de ocurrir durante el período de 20 días comprendido entre mayo 25 y junio 13.

3. Cada evento ha de ocurrir en solo uno de esos veinte días y solamente puede ser "detectado" si es "cotejado" en ese día.

4. Cada "coteio" que se hace sobre un evento le cuesta a la

5. Cada evento que sucede y pasa sin ser detectado le cuesta a la gerencia $5.00.

6. El objetivo suyo como gerente es conseguir un balance entre el costo de "cotejar" y el costo de "no detectar" los eventos de manera que se minimize la suma de estos dos costos.

Uso del Simulador

Sus decisiones "diarias" serán comunicadas a un simulador. Esto se hará por medio del teletipo, el cual le pedirá a usted que le informe qué eventos desea cotejar en cada uno de los 20 días de la simulación. A su vez, el simulador lo mantendrá a usted informado sobre cuáles de los eventos "cotejados" son "detectados". El simulador funciona como sigue:

1. Al principio del experimento, el teletipo escribirá:

TODAY IS 5-25 (mayo 25)

Inmediatamente, el simulador le indicará que está listo para recibir sus instrucciones sobre qué eventos cotejar ese día escribiendo:

CHECKS ?

Usted deberá entonces escribir el número de identificación para cada evento que desea cotejar ese día, dejando un espacio entre cada evento y oprimiendo "return" cuando haya entrado el último evento. Los 3 dígitos del número de identificación deben ser escritos para cada evento que desea cotejar. De otra manera el simulador escribirá el mensaje:

? INPUT DATA NOT IN CORRECT FORM - PLEASE RETYPE

2. Inmediatamente despues que usted escribe los eventos que desea cotejar, el simulador determinará cuáles de los eventos cotejados ocurrieron ese día y por lo tanto fueron detectados. El simulador entonces escribirá los números de identificación de los eventos cotejados y detectados como en los ejemplos que siguen:

```
TODAY IS: 6-4
-------------

CHECKS ?
? 121 097 168
CHECKED:  121 097 168   DETECTED: 168
```

(Esta información deberá ser anotada para evitar cometer el error de volver a cotejar el "168")

```
TODAY IS: 6-5
-------------

CHECKS ?     (No escribió todos los dígitos del "097")
? 97 177
? INPUT DATA NOT IN CORRECT FORM--PLEASE RETYPE
? 097 177
CHECKED:  097 177   DETECTED: NONE


TODAY IS: 6-6
-------------

CHECKS ?
?            (no deseaba cotejar ese día y
CHECKED:  NONE      oprimió "return")
```

3. La información dada por el simulador en cuanto a los eventos que son detectados deberá ser anotada para evitar cometer el error de volver a cotejar un evento que ya ha sido detectado. Estas anotaciones se deberán hacer en el mismo informe provisto.

4. Al final del último día (junio 13) el simulador escribirá un resumen de su ejecutoria, incluyendo una lista de las fechas en que realmente sucedieron cada uno de los eventos como en el ejemplo que sigue:

```
******** SUMMARY OF RESULTS FOR THE RUN ********

54 CHECKS @ $1/CHECK = $54
6 MISSES @ $5/MISS = $30

TOTAL COST = $84

ACTUAL EVENT DATES

EVENT ID.   DATE
    004      6-6
    009      5-28
     :        :
    168      6-4
    171      5-31
    173      6-5
    177      6-4
    186      6-1
```

5. Usted deberá revisar este resumen para verificar que la información en cuanto a eventos cotejados y detectados es correcta. Una vez hecho esto deberá oprimir la tecla "return" para que el simulador prosiga.

6. El simulador entonces procederá a escribir una serie de preguntas que usted deberá contestar siguiendo las instrucciones por el teletipo. Una vez contestadas las preguntas habremos concluido el experimento.

DECLARACION DE CONSENTIMIENTO

He leído y entiendo el procedimiento experimental descrito arriba. Deseo participar en dicho procedimiento, entendiendo que estoy libre de retirar mi consentimiento y participación en el mismo en cualquier momento si así lo deseare.

Firmas _____
Sujeto

_____
Testigo

_____
José Amador
Investigador Principal
Colegio de Administración de Empresas
Recinto Universitario de Mayaguez
Mayaguez, Puerto Rico

Instructions

Introduction

The purpose of this experiment is to measure the effectiveness of a managerial report. The report is intended to aid a manager in "detecting" a series of events that are due to occur in the near future and are of interest to him. These events occur at random approximately every 20 days, and when they do occur, they are "detectable" only during one day. It is to the manager's advantage to detect these events when they occur, as there is an opportunity cost associated with each event that occurs and goes undected (it will not occur again until about 20 days). The reports under study have been prepared on the basis of past event occurrence data and consist of estimates of the next occurrence dates for a number of such events. The general format of the report studied is as follows:

Event I.D.	Expected Occurrence Date

The idea behind the experiment is to measure the effort that variants of this format might have on its effective use. You will receive one of various experimental formats for this report, and, during a period of 20 simulated days, you will use the report to help you "detect" a number of events which according to the report are due to occur during those days.

Game Rules

During the experiment you will play the role of the manager in charge of deciding how many and which events to check for on each successive day. The rules you will want to keep in mind when making your "check" decisions are the following:

1. You will receive a report indicating the events that you want to "check" during the next 20 days. Each event will be identified with a three-digit number on the left margin of your report. To the right of these numbers you will find information about the estimated occurrence date of each event.

2. All events on the report will occur during the 20-day period between May 25 and June 13.

3. Each event will occur on only one of these 20 days, and can only be "detected" if "checked" on that day.

4. Each "check" made on an event will cost management $1.00

5. Each event that occurs and is not detected will cost management $5.00.

6. Your objective as manager is to compromise between the cost of "checking" and the cost of "missing" so as to minimize the sum of these two costs.

Use of the Simulator

Your daily check decisions will be input to a computer simulator. This will be done via a teletype terminal, which will ask you to enter the I.D. number of the events you want to check on each day. In turn, the simulator will inform you which of the events you "check" are "detected," as follows:

1. The simulator starts by printing:

TODAY IS 5-25 (May 25)

Immediately, the simulator will ask for your day's check decision:

CHECKS?

You will then enter the three-digit I.D. number for each event you want to check on that day, leaving a space between each number entered and pressing the "return" key after the last number is entered. All 3 digits must be entered for each event checked. Otherwise, the simulator will print:

? INPUT DATA NOT IN CORRECT FORM--PLEASE RETYPE

2. Immediately after entering the events to be checked, the simulator will determine which of the events checked occurred on that day and thus, were detected. The simulator will then proceed to print the I.D. number of the events checked and detected as in the examples that follow:

TODAY IS: 6-4

CHECKS?
? 121 097 168
CHECKED: 121 097 168 DETECTED: 168

(The feedback from the simulator should be recorded to avoid the mistake of checking "168" again).

TODAY IS 6-5

CHECKS?
? 97 177 (Did not use all 3 digits on "097")
? INPUT DATA NOT IN CORRECT FORM--PLEASE RETYPE
? 097 177
CHECKED: 097 177 DETECTED: NONE

3. The feedback from the simulator on events checked and detected should be recorded to avoid checking an event that has already been detected. All writing should be done on the report provided.

4. After the last day of the run (June 13) the simulator will proceed to print a summary of your performance, including a list showing the actual dates on which each event occurred, as follows:

```
********SUMMARY OF RESULTS FOR THE RUN********

54 CHECKS @ $1/CHECK = $54
6  MISSES @ $5/MISS = $30

TOTAL COST = $84

ACTUAL EVENT DATES

EVENT ID.   DATE

   004      6-6
   009      5-28
    .        .
    .        .
    .        .
   168      6-4
   171      5-31
   173      6-5
   177      6-4
   186      6-1
```

5. You should then revise this summary to verify that the information on checks and misses is correct. Once done this, you will press "return."

6. The simulator will then proceed to print a short questionnaire that you must answer following the instructions it will also print. Once done this, we will have concluded the experiment.

STATEMENT OF CONSENT

I have read and understand the instructions to the experimental procedure described above. I wish to participate in the experiment, understanding that I am free to withdraw my consent and participation at any time if I so desired.

Signatures _____
Subject

_____
Witness

_____
José Amador
Principal Investigator
College of Business Administration
University of Puerto Rico, Mayaguez
Mayaguez, Puerto Rico

BIOGRAPHICAL SKETCH

José A. Amador was born December 23, 1947, in Aguadilla, Puerto Rico. He received his elementary and secondary education at Colegio San Carlos, Aguadilla, and graduated from San Carlos High School in May, 1965. He attended the University of Puerto Rico, Mayaguez Campus, from 1965 to 1969 and received a Bachelor's degree with a major in Business Administration in May, 1969.

In September 1970, José Amador was granted an appointment and license from the University of Puerto Rico to undertake graduate studies. He entered the graduate program in Business Administration at the University of Florida, and in August, 1971, received a Master of Business Administration degree. In August, 1974, he received a Master of Science degree from the University of Florida with a major in Industrial and Systems Engineering.

José Amador is presently an Assistant Professor in the College of Business Administration at the University of Puerto Rico. He is a member of Phi Eta Mu fraternity, Beta Gamma Sigma honorary business society, and the American Institute for Decision Sciences. He is married to the former Maria L. Lopez of Aguadilla, Puerto Rico, and is the father of two sons, José Angel and Juan Carlos.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Richard A. Elnicki, Chairman
Associate Professor of Management

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Christopher B. Barry
Associate Professor of Management

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Jack M. Feldman
Associate Professor of Management

I certify that I have read this study and that in my opinion it confroms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Thom J. Hodgson
Associate Professor of Industrial and Systems Engineering

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Richard R. Jesse, Jr.
Assistant Professor of Management

This dissertation was submitted to the Graduate Faculty of the Department of Management in the College of Business Administration and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 1977

Dean, Graduate School